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The Use of Digital Games to Enhance the Physical Exercise Activity of the Elderly

A Case of Finland

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Abstract

According to the World Health Organization (WHO), population ageing is a global phenomenon, which brings both challenges and opportunities for society. The current longer expected lifespan can create opportunities for the elderly to contribute in many ways to their families and communities. However, it greatly depends on their quality of life, which is affected by many factors, including physical and functional health, social well-being, and cognitive abilities. The WHO (2012) states that physical health is one of the indicators for the elderly's quality of life, and it declines with increasing age. Participation in regular physical exercises can help the elderly improve their physical and mental health, and this has been aided by the use of modern technologies to promote the elderly's physical and functional health.

Of these latest technologies, digital games have shown promise to improve and enhance the elderly's physical activities through fun and engaging gameplay. The literature highlights that some commercial games in the market (e.g. Microsoft Kinect-Sports and Nintendo Wii Sports games) have the potential to improve the elderly's physical health such as gait, balance, and fall prevention. However, researchers argue that these commercial games are not designed specifically for the elderly and their physical exercise activities. They state that most commercial games are not user-friendly for the elderly whose functional and physical abilities are limited due to their advanced years. The literature points out that more studies need to be undertaken to understand the usability and usefulness of digital games for physical exercise activities so that game designers can create elderly-friendly digital games in the future. In Finland, the government has been focusing on promoting healthy ageing and increasing home care services for the elderly. In recent years, Finnish researchers have used digital games to promote older Finns' healthy and active ageing. The existing literature, whilst showing the potential of digital games for elderly Finns' physical health, also acknowledges further research is needed particularly in the context of Finland.

Thus, in this study, we aimed at investigating digital games to specifically assess their applications for older Finns' physical activities, focusing on the quality of users' experiences, and their reported ease of use and perceived usefulness. We used the mixed methods approach, which applies both qualitative and quantitative research methods. The study design included four stages: requirements gathering, analysis and design, prototyping, and evaluation. Firstly, we conducted pre-studies to elicit users' requirements. This was followed by the analysis of the resulting data to identify trends and patterns, which fuelled ideas in the brainstorming game design and development

phases. The final product was a digital game-based physical exercise called the *Skiing Game.* We then evaluated the *Skiing Game* in Finland with 21 elderly Finns (M=7, F=14, Average Age =76). By using questionnaires, observation, and interviews, we investigated user experiences, focusing on the game's usability, and usefulness for enhancing the physical activity and wellbeing of the elderly. We also conducted a comparative test of the *Skiing Game* in Japan with 24 elderly Japanese participants (M=12, F=12, Average Age = 72) to further understand non-Finnish elderly users' experiences.

The findings from the usability study of the *Skiing Game* in Finland demonstrated that elderly Finns had a positive experience in the gameplay, and their motivation was noticeably high. It also confirmed that elderly Finns have a genuine interest in digital game-based exercises and strong intentions to play digital games as a form of physical exercise in the future. Although prior to the study most of them had negative views and misconceptions about digital games, after the gameplay their attitudes were decidedly positive. They acknowledged that whilst playing digital games could be an alternative way of exercising for them their use would primarily be when they don't have access to their usual non-digital physical exercise. The Japanese usability of the *Skiing Game* showed that the elderly Japanese people also had positive user experiences in playing digital games, and also intend to use them in the future. Similarly, after playing the game they reported that their attitudes towards digital games become positive, and indicated playing digital games could be an alternative way of exercising. Although the comparison of the two studies suggests that the elderly Finns had relatively more positive experiences whilst playing the *Skiing Game*, compared to their Japanese counterparts, in general, both groups had a positive experience in the gameplay and showed interest in digital games as an alternative exercise.

Based on the usability lessons learned from these two studies, recommendations for practitioners and designers regarding improvements in game design and development are made in this report. Implementing these modifications into future designs and further development of digital games for the elderly will improve their commercial viability and user uptake. The findings from this study can provide valuable insights, particularly for Finnish policymakers and healthcare practitioners who are keen to introduce digital games into the aged-care sector in Finland. The studies have also provided valuable insights into the optimal methods for introducing Finnish digital games to international markets, in particular, digital games tailored specifically for the physical exercise needs and motivations of the elderly. By taking into consideration the limitations of the study, we provide our future studies and further improvements of the game to be conducted.

Abstract (in Finnish)

Maailman terveysjärjestö WHO:n mukaan väestön ikääntyminen on globaali ilmiö, joka tuo yhteiskunnille sekä haasteita että mahdollisuuksia. Alati pitenevä elinaika luo vanhuksille monia mahdollisuuksia osallistua ja auttaa perheitään ja yhteisöään. Tämä kuitenkin riippuu suurelta osin heidän elämänlaadustaan, mihin vaikuttaa monet seikat mukaan lukien fyysinen ja toiminnallinen terveys, sosiaalinen hyvinvointi ja kognitiiviset kyvyt. WHO (2012) mainitsee että fyysinen terveys on yksi vanhusten elämänlaadun indikaattoreista ja että se laskee iän myötä. Osallistuminen säännöllisiin fyysisiin harjoituksiin voi auttaa vanhuksia parantamaan heidän fyysistä ja henkistä terveyttään, ja modernin teknologian käyttö voi edistää vanhusten fyysistä ja toiminnallista terveyttä.

Näistä teknologioista lupaavin on ollut digitaaliset pelit, jotka voivat tehostaa vanhusten fyysisiä aktiviteetteja hauskan ja mukaansa tempaavan pelaaminen kautta. Tutkimuksissa on havaittu, että joillakin markkinoilla olevilla kaupallisilla peleillä (esim. Microsoft Kinect Sports ja Nintendo Wii Sports) on potentiaalia parantaa vanhusten fyysistä terveyttä kuten askellusta, tasapainoa ja kaatumisen välttämistä. Samassa yhteydessä kuitenkin on todettu, että näitä kaupallisia pelejä ei ole suunniteltu erityisesti vanhuksia ja heidän fyysisiä harjoituksia varten. Monet kaupallisista peleistä eivät ole käyttäjäystävällisiä vanhuksille, joiden korkea ikä voi rajoittaa heidän toiminnallisia ja fyysisiä kykyjä. On siis olemassa tarve lisätutkimukselle, jotta digitaalisten pelien käytettävyys ja käyttökelpoisuus fyysisissä harjoitusaktiviteeteissa voitaisiin ymmärtää, niin että pelisuunnittelijat voisivat luoda tulevaisuudessa vanhusystävällisiä digitaalisia pelejä. Suomen valtio on pyrkinyt edistämään tervettä ikääntymistä ja lisäämään kotihoidon palveluita vanhuksille. Viime vuosina suomalaiset tutkijat ovat tarkastelleet digitaalisten pelien mahdollisuuksia edistää suomalaisten vanhusten tervettä ja aktiivista ikääntymistä. Vaikka tulokset osoittavatkin digitaalisten pelien potentiaalin suomalaisten vanhusten fyysisessä terveydenhoidossa, ne indikoivat myös lisätutkimuksen tarvetta erityisesti suomalaisessa kontekstissa.

Tässä väitöstutkimuksessa tarkastellaan digitaalisia pelejä arvioiden erityisesti niiden soveltuvuutta suomalaisvanhusten fyysisiin aktiviteetteihin ja keskittyen käyttäjäkokemuksen laatuun ja pelien raportoituun helppokäyttöisyyteen ja havaittuun hyödyllisyyteen. Lähestymistapana on käytetty monimenetelmätutkimusta (mixed methods), mikä soveltaa sekä kvalitatiivisia että kvantitatiivisia tutkimusmetodeja. Tutkimustyö sisälsi neljä vaihetta: vaatimusten keruu, analyysi ja suunnittelu, prototyypitys ja evaluointi. Aluksi suoritetulla ennakkokartoituksella selvitettiin käyttäjävaatimukset. Tätä tietoa analysoitiin trendien ja rakenteiden tunnistamiseksi, mitkä toimivat pohjana seuraavan vaiheen pelisuunnitteluun ja pelinkehitykseen. Työn lopputulos oli digitaaliseen peliin pohjautuva fyysinen harjoitus nimeltä Skiing Game. Seuraavaksi tätä peliä evaluoitiin Suomessa 21 vanhukselle tehdyllä käyttäjätutkimuksella (miehiä 7, naisia 14, keskimääräinen ikä 76). Käyttäjäkokemusta arvoitiin kyselyiden, havaintojen ja haastatteluiden avulla keskittyen pelin käytettävyyteen ja mahdollisuuksiin parantaa vanhusten fyysistä aktiviteettia ja hyvinvointia. Vertaileva testi järjestettiin Japanissa 24 japanilaisvanhuksen kanssa

(miehiä 12, naisia 12, keskimääräinen ikä 72), jotta voitaisiin ymmärtää ei-suomalaisten vanhusten käyttäjäkokemusta.

Skiing Game -pelin käytettävyystutkimuksen löydökset osoittavat, että suomalaisvanhusten pelikokemus oli positiivinen ja että heidän motivaationsa oli huomattavan korkea. Tutkimus myös vahvisti sen, että suomalaisvanhukset ovat aidosti kiinnostuneita digitaalisiin peleihin perustuvista harjoituksista sekä toivovat näkevänsä niitä tulevaisuudessa yhtenä fyysisen harjoittelun muotona. Vaikka ennen tutkimusta useimmilla heistä oli negatiivinen näkemys ja virhekäsityksiä digitaalisista peleistä, pelaamisen jälkeen heidän asenteensa oli selvästi positiivinen. Vaikka digitaalisten pelien pelaaminen voisi olla vaihtoehtoinen tapa harjoitella, heidän mielestään sille olisi käyttöä pääasiassa silloin kun heillä ei ole mahdollisuus tehdä heidän tavallisia, ei-digitaalisia fyysisiä harjoituksia. Japanilaisten parissa tehty käytettävyystutkimus osoitti, että myös japanilaisvanhusten käyttäjäkokemus digitaalisista peleistä oli positiivinen ja että myös he halusivat käyttää niitä tulevaisuudessa. Samankaltaisesti myös he raportoivat, että heidän suhtautumisensa digitaalisiin peleihin muuttui positiiviseksi ja että digitaalisten pelien pelaaminen voisi olla vaihtoehtoinen tapa harjoitella. Vaikka näiden kahden tutkimuksen vertailu antaa ymmärtää, että suomalaisvanhuksilla oli suhteessa enemmän positiivisia kokemuksia Skiing Game -pelin parissa japanilaisvanhuksiin verrattuna, yleisesti ottaen molempien ryhmien kokemus oli positiivinen ja kumpikin osoitti kiinnostusta digitaalisiin peleihin vaihtoehtoisena harjoittelumuotona.

Näiden kahden käytettävyystutkimuksen perusteella tässä tutkimuksessa annetaan suosituksia sekä hoitoalan ammatti-ihmisille että pelisuunnittelijoille, joiden pohjalta voitaisiin parantaa sekä pelisuunnittelua että pelinkehitystä. Näiden modifikaatioiden implementointi tuleviin tuotteisiin sekä digitaalisten pelien jatkokehitys vanhuksille tulevat parantamaan niiden kaupallista kannattavuutta ja käyttäjämääriä. Tämän tutkimuksen löydökset voivat tarjota arvokasta näkemystä, erityisesti suomalaisille päättäjille ja terveydenhuollon ammattilaisille, jotka haluavat ottaa käyttöön digitaalisia pelejä ikääntyneiden ihmisten hoidossa. Tutkimustyö on myös parantanut näkemystä siitä, miten suomalaisia digitaalisia pelejä voidaan esitellä tehokkaasti kansainvälisille markkinoille silloin kun ne on erityisesti sovitettu fyysisen harjoittelun tarpeisiin ja vanhusten motivointiin. Tämän tutkimuksen rajoitukset huomioiden tutkielma esittelee aiheita lisätutkimukselle sekä parannusehdotuksia tuleviin peleihin.

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To each of you my deepest gratitude and love.

List of Original Publications

I. Pyae, A., Raitoharju, R., Luimula, M., Pitkäkangas, P., & Smed, J. (2016). Serious games and active healthy ageing: a pilot usability testing of existing games. *International Journal of Networking and Virtual Organisations 16*(1). doi: DOI: 10.1504/IJNVO.2016.075129

II. Pyae, A., Luimula, M., & Smed, J. (2015). Rehabilitative games for stroke patients. *EAI Endorsed Transactions on Serious Games*, 15 (4): e2. doi: http://dx.doi.org/10.4108/sg.1.4.e2

III. Pyae, A., Luimula, M., & Smed, J. (2016). Pre-studies on using digital games for the elderly's physical activities. In H. Li, P. Nykänen, R. Suomi, N. Wickramasinghe, G. Widén, & M. Zhan (Eds.), *Building Sustainable Health Ecosystems: 6th International Conference on Well-Being in the Information Society, WIS 2016, Tampere, Finland, September 16-18, 2016, Proceedings* (pp. 82-96). Cham: Springer International Publishing. doi: https://doi.org/10.1007/978-3-319-44672-1_8

IV. Pyae, A., Liukkonen, T. N., Saarenpää, T., Luimula, M., Granholm, P., & Smed, J. (2016). When Japanese elderly people play a Finnish physical exercise game: A usability study. *Journal of Usability Studies, 11*(4), 131–152.

V. Pyae, A., Liukkonen, T. N., Luimula, M., Kattimeri, C., & Smed, J. (2017). Investigating the Finnish elderly people's user experiences in playing digital game-based skiing exercise: A usability study. *Gerontechnology*, 16(2), 65-80 https://doi.org/10.4017/gt.2017.16.2.002.00

VI. Pyae, A., Luimula, M., Liukkonen, T. N., & Smed, J. (2017). Investigating the Finnish elderly people's attitudes and motivation towards digital game-based physical exercises. *Finnish Journal of eHealth and eWelfare*, 9(4), 265-283.

VII. Pyae, A., Joelsson, T., Saarenpää, T., Luimula, M., Kattimeri, C., *et al*. (2017). Lessons learned from two usability studies of a digital skiing game with elderly people in Finland and Japan. *International Journal of Serious Games*, 4 (4), 37-52.

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Contribution to the Publications

Publication No	Contributions
I	My contribution in this study includes the literature review on the existing research and commercial games that show the potential for promoting the elderly's physical activity. I also participated in the research team to conduct observations and interviews at the elderly service homes in Finland. Furthermore, I was involved in the GSH project schedule, research planning, and international collaboration. In the manuscript, I contributed as the main author, including the literature review, methodology, data analysis, findings, and discussion.
II	In this project, I conducted a literature review on motivational factors for stroke patients particularly the elderly in the context of rehabilitation. I also involved in the usability evaluation of existing commercial games and Puuha Group's game with the researchers from the Turku Game Lab, Finland. I contributed to the literature review, participants recruitment, study design, data collection, and analysis. In the manuscript, as a first author, I contributed to the literature review, methodology, data collection, analysis, findings, and discussion.
III	In this project, I participated as a researcher by collaborating with the researchers from the Turku Game Lab in Finland. I was also involved in the research activities such as literature review, pilot usability evaluation of existing games, and interactive multimodal input devices. In the manuscript, as a first author, I contributed to the literature review, methodology, data collection, analysis, and discussion.
IV	In this project, I participated in the study design, methodology, and data collection. I reviewed the qualitative and quantitative data collected from the Japanese usability study of the *Skiing Game*, followed by the data analysis and findings. Then, I proposed usability guidelines for designing digital games for the elderly. In the manuscript, as a first author, I contributed to the literature review, study design, methodology, data collection, analysis, findings, and discussion.
V	My contribution to this Finnish usability study of the *Skiing Game* includes participants recruitment, literature review, methodology, data collection, analysis, and findings. In the manuscript, as a first author, I contributed to the literature review, methodology, analysis, findings, and discussion.
VI	As a researcher, I participated in this usability study working on study design, methodology, participants recruitment, data collection, analysis of data, and manuscript preparations. In this manuscript, as a first author, I contributed to the literature review, study design and methodology, analysis, findings, and discussion.
VII	I contributed to this research publication by analyzing and comparing the findings from the Finnish and Japanese usability studies of the *Skiing Game*. As a first author, I contributed to the manuscript that includes the literature review, methodology, analysis, findings, and discussion.

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Chapter 1
Introduction

This doctoral thesis examines the usability, user experiences, and usefulness of digital game-based physical exercise activity for elderly Finns to promote their participation in physical exercises and rehabilitation activities. In this study, we design, implement, and assess a digital game-based exercise called the *Skiing Game* through usability studies in both Finland and Japan, and make recommendations for further targeted applied research and development to better serve elderly clients' needs in a global market. The thesis comprises seven chapters, and Chapter 1 outlines the working definitions and terms used in this thesis, population ageing and its challenges, the potential of digital games for the elderly's physical exercise activities, research gaps, research questions, study design and process, the significance of this research, and the logic behind the structure of the thesis.

1.1 Definitions

1.1.1 The Elderly

The definition of when an individual is regarded as an '*Older Person*' or in more general terms when a cohort can be categorised as '*The Elderly*' can be variable and somewhat arbitrary. There is no general agreement on a specific point in life at which a person is considered old (World Health Organization, 2002). Every society has its own definition of old age, which can be influenced by cultural or economic factors and even standards of public health (Sanderson & Scherbov, 2008). According to the United Nations, people aged 60 years and above are defined as '*older people*' (United Nations Fund for Population Activities, 2012). The World Health Organization (2002) states that in most developed countries, an '*Older' or 'The Elderly* ' person is regarded as anyone 65 years and above. Other than chronological age, '*The Elderly'* or '*Older Person*' is generally identified as such at the point their physical, functional, and mental capacities begin to decline (United Nations Fund for Population Activities, 2012). According to WHO (2002), in developed countries, chronological age plays an important role in defining '*old age*', whereas in many developing, and certainly, in the least developed countries, other socially constructed markers are significant (e.g. role changes and physical decline). In the European Union (eurostat, 2015), '*The Elderly*' or '*Older Person*' refers to anyone aged 65 years or above. According to the United Nations Population Fund (2014), in Asia, 60 years and above is the benchmark of being an '*Elderly'* or 'Older'

person. In this thesis, the working definition of '*The Elderly*' will be 65 years and above - in line with WHO (2012).

1.1.2 User Experience and Usability

According to the User Experience Professionals Association (UXPA), user experience can be defined as "*every aspect of the user's interaction with a particular system or device or product that make up the user's perception of the whole* " (UXPA, 2019). Hassenzahl (2013) states that user experience is not about fanciful interfaces; whereas, it is about creating an experience for users in interacting and using a particular system or device. The International Organization for Standardization (2008) defines that user experience is a user's perceptions and responses resulting from the use or anticipated use of a particular system, device or product. In this study, we used the term '*user experience*' in the digital game context (the definition of digital game is stated in sub-section 1.1.3). User experience, in this thesis, refers to a user's perception of a particular digital game system, as well as experience in interacting or playing with such digital game systems.

The definition of usability is described in ISO 9241-11 that the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (Bevan, Carter, Earthy *et al.*, 2016, p. 3). The term '*usability*' is also described as "*when a product or service is truly usable, the user can do what he or she wants to do the way he or she expects to be able to do it, without hindrance, hesitation, or questions*" (Rubin, 2008, p. 4). Usability means to the extent to which a particular software or system is intuitive and effective for users trying to accomplish the tasks at hand taking into account human limits in memory, perception, and attention (Isbister & Schaffer, 2008, pp. 3-4). In this thesis, we use the term '*usability*' in the context of digital games that refers to optimizing a player's engagement and achieving specified goals with effectiveness, efficiency, motivation, and satisfaction in playing a particular digital game system (Rajanen & Rajanen, 2018).

1.1.3 Physical Exercise Activity

According to the World Health Organization (WHO) (2017), physical activity includes leisure-time physical activity (e.g. gardening), transportation (e.g. walking or cycling), occupational (e.g. engaged in work), household chores, play, games, sports or planned exercise, in the context of daily, family, and community activities. Taylor (2014)

also states that physical activity refers to any activity that has an energy cost including housework, shopping, gardening, and structured exercise programs. According to Crocker, Forster, Young *et al.* (2013), physical rehabilitation can be defined as "*an intervention that aims to maintain or improve the physical function of an individual, and it involves increasing the physical exertions of an individual elderly in an active rehabilitation*". In this thesis, we used the term '*Physical Exercise Activity*' that refers to physical activity of the elderly or rehabilitative physical exercises for them.

1.1.4 Digital Games and Digital Game-based Physical Exercise Activity

In this thesis, we use the term '*Digital Games*', which refers to "*games that are played through technology such as televisions, computers, game consoles, and mobile devices, and which brought an interactive approach to game play*" (Hall & Marston, 2016, p. 581). Digital games, in this research, basically include commercial games (e.g. Microsoft Xbox Sports games) as well as computer games developed by the game developers from Puuha Group and the Turku Game Lab in Finland (e.g. SportWall games). Furthermore, we use the term '*Digital Game-based Physical Exercise Activity*' that refers to '*the use of digital games in a physical exercise activity for both regular physical activity and rehabilitation for the elderly*'. According to the World Health Organization (WHO) (2017), regular physical activity for the elderly includes leisure-time physical activity, playing games, and exercises. For rehabilitation activity, Cameron and Kurrle (2002) state that rehabilitation is basically a process that aims to restore the functional capacities of a disabled person, and the main goal of a particular rehabilitation program for the elderly is to assist them to manage personal activities of daily living without the assistance of another person, as well as to minimize the need for external assistance through the use of adaptive techniques, equipment, and intervention. In this study, the *Skiing Game* is designed and implemented for two main purposes: 1) to promote healthy elderly Finns' participation in regular exercise activity and 2) to help elderly Finns who need a rehabilitative exercise activity through an interactive game-based intervention. Thus, in this thesis, the term '*Digital Game-based Physical Exercise Activity*' is used accordingly while referring to the use of an interactive game system for the elderly to achieve both regular physical activity and rehabilitative training.

1.2 Population Ageing

Population ageing is a global phenomenon (United Nations, 2013). Many countries in the world are experiencing rapid growth in the proportion of their total population who are elderly (United Nations, 2015). According to the World Population Ageing Report (2015), between 2015 and 2030 the global population aged 60 years and above will grow by 56%, from 901 million to 1.4 billion. The UNFPA (2016) highlights that the quantum of the elderly as a proportion of the total population is rising exponentially. Currently, people aged 60 years and above comprise 12.3% of the global population, but by 2050, it is expected to be closer to 22%. The World Population Prospects: The 2017 Revision by United Nations (2017) also highlights that the number of persons aged 60 years and above is predicted to more than double by 2050 and to more than triple by 2100, increasing from 962 million worldwide in 2017 to 2.1 billion in 2050, and 3.1 billion in 2100 respectively.

Many European countries are also facing the problem of a net decline in population due to lower birth rates (European Commission, 2014), and lower fertility leads to ageing populations (United Nations, 2017). By 2020, a quarter of Europeans will be 60 years and above. Among the European countries that are facing the challenge of ageing population, Finland is no exception to this according to national data published as Statistics Finland (2017). Finland's population is ageing faster than most other nations in the European Union (EU). According to the National Institute for Health and Welfare (2018), Finland is rapidly ageing and it has one of the oldest populations among the European countries. In 2015, those Finns aged 65 years and above comprised only 19.4% of the total population but by 2050 this will increase to 26.9% (Demos Helsinki, 2016). It is estimated the proportion of Finland's total population aged 65 years and above will increase from the present 19.9% to 26% by 2030 and to 29% by 2060 (Statistics Finland, 2018). A similar trend can be seen in other regions of the world. For instance, in 2002, the proportion of the total population of Asia aged 65 years and above was an estimated 6 %, but by 2050, it will rise to 18% (East West Center, 2010). Further, in Southeast Asia, Singapore's population is also ageing so rapidly that its median age increased from 34 years in 2000 to 40 years in 2015 (Malhotra, Bautista, Müller *et al.*, 2018).

1.3 Challenges of Population Ageing

Population ageing brings many challenges for society, especially for governments and public authorities. These challenges include increased demands upon

age-related services, placing extra pressures upon the public purse to provide adequate funding for pensions and other social security provisions. Spikes in both acute and chronic age-related health issues place extra demands on healthcare systems with flow-on impacts upon the labour market and the economy. According to Kunz (2007), the negative consequences of rapid growth in the elderly population include increasing expenditure for pensions and potential labour shortages. Furthermore, the elderly population will have a great impact on the organization and delivery of healthcare systems, which is associated with a growing shortage of healthcare workers such as nurses and paraprofessionals (Wiener & Tilly, 2002). Promoting a healthy and independent lifestyle for the elderly is a key challenge worldwide, demanding urgent action (WHO, 2012). Other challenges include emergency transportation for the elderly (Lowthian, Jolley, Curtis *et al.*, 2011), age-friendly environment and society (Sander, Oxlund, Jespersen *et al.*, 2014), and unemployment and income insecurity (Oluwabamide & Eghafona, 2012).

In Finland, the rising trend towards a predominantly elderly population poses many challenges and calls for broad reforms to existing social service systems in order to efficiently and effectively deliver a broad range of social and healthcare services (Satka & Hämeenaho, 2015). Heikkilä (2012) points out that population ageing has emerged as one of the major problems in developed countries- especially in Europe - and the problems posed by the elderly population will significantly impact future social planning. According to the Ministry of the Interior Publications (2018), Finland has been facing a labour shortage in the social services and healthcare sectors, as a direct consequence of its ageing population's escalating need for higher levels of social services, in-home assistance and healthcare than any other age group. According to Voutilainen (2015), the Finnish government and public authorities have been focusing on developing and promoting the best ways for its citizens to maintain optimal health and independence as they age, by increasing home care and developing a full range of support services for its elderly. According to Zhu (2017), municipalities throughout Finland, organize services for the elderly around two primary goals: to make their lives easier, and help them live in their own homes as long as possible.

1.4 Importance of Physical Exercises for the Elderly

Ageing represents a progressive decrease in function and capability over time (Austad, 1997; Bowen & Atwood, 2004). According to the American Psychological Association (2017), the elderly experience natural age-related changes, which include

physical and functional decline, cognitive decline, social isolation, and disengagement. Depending on the rate and pace of these changes the elderly experience either a gradual or rapid decline in their quality of life in their later decades (Smith & Reavey, 1997).

As they physically decline, the elderly people experience difficulties in carrying out even the simplest tasks of daily living and function less ably across a range of activities (Milanović, Pantelić, Trajković *et al.*, 2013). Furthermore, the physical and functional decline in old age can be compounded by an increased risk of loss of mobility and intellectual or sensory disability (Chappell & Cooke, 2010). According to Chia, Cheng, Hnin *et al.* (2018), ageing is associated with increased chronic diseases and functional disabilities. Common physical changes in the elderly include sensory loss, vision and hearing impairment, and muscle weakness (Smith & Gove, 2005). According to Manini (2014), the elderly are generally at high risk for age-related physical disabilities, as well as age-related chronic diseases. Those who have lost independent mobility are less likely to remain in the community, and they tend to have higher rates of disease, poorer quality of life, and greater risk of social isolation (Manini, 2014).

Functional independence in old age is one of the important indicators for the quality of life for the elderly. The World Health Organization (2002) recommends participation and engagement in regular physical activities and exercises by the elderly as a proven means of improving physical fitness and functional health, as well as cognitive ability. Chia, Cheng, Hnin *et al.* (2018) confirm that physical activities can contribute to healthy and successful ageing. Basic activities best suited to the needs and capabilities of the elderly include leisure-time physical activities (e.g. walking, dancing, and gardening), playing games and sports, and participation in regular physical exercises. Vereijken and Helbostad (2018) state that an active lifestyle is one important contributor to keeping the elderly healthy and independent for as long as possible. Being engaged in regular physical exercises can minimize their functional decline (Lau, Ohinmaa, & Johnson, 2011). More importantly, physical exercises play an important role in improving the elderly's physical health and fitness, social engagement, cognitive health, and abilities (Wan & Wong, 2014).

1.5 Digital Games for the Elderly's Physical Exercise Activity

Technological improvements and advancements today create opportunities for enhancing the elderly's quality of life through more effective delivery and ongoing monitoring of services and efficient communication relevant to their healthcare, physical and social well-being, and security (The Independent Age, 2017). Of these

modern technologies, digital games, in particular, have shown great potential for improving the physical and psychosocial well-being of the elderly (Li, Xu, Tan *et al.*, 2017). Basically, the contents of digital games (e.g. graphics, sound, characters, and levels) are interactive, visually appealing, entertaining, and fun. In digital games, brightly coloured graphics, a wide range of sound effects, strong storylines, the immediacy of rewards, and range of skills levels can create an engaging and enjoyable platform for players (Pyae, Tan, & Gossage, 2013d). Whilst originally digital games were primarily designed to be fun for users to play, they can have broader applications and can be effectively used as an enjoyable tool for physical training for players (Zhang & Kaufman, 2015). According to the existing literature, for more than a decade, people have used digital games as a tool to motivate the elderly to engage in regular physical exercise routines. This claim is supported by Aarhus, Grönvall, Larsen *et al.* (2011) stating that digital games can motivate the elderly to engage in regular exercises. Compared with traditional physical exercise interventions, digital game-based exercises can provide playful, entertaining, engaging, and fun activities for players (Wiemeyer & Kliem, 2011). Sauvé, Renaud, Kaufman *et al.* (2015) also advocate that an increasing number of studies has demonstrated that digital games, when used by the elderly, can have a positive impact on their engagement with physical training and also their level of social connectivity.

In the existing literature, researchers have reported the positive benefits of using digital games for the elderly's physical health and rehabilitation. According to Valenzuela, Okubo, Woodbury *et al.* (2018), digital games can provide a sustainable means of promoting physical activity in the elderly population. This statement is supported by Nguyen, Ishmatova, Tapanainen *et al.* (2017) claiming that in addition to their entertainment values, digital games can provide beneficial therapeutic and rehabilitation effects for the elderly that can improve their physical health and well-being. There can be seen a number of studies in the literature claiming that digital games can create positive outcomes for the elderly through a digital game-based exercise intervention. For instance, Ribeiro, Vieira, Beline *et al.* (2018) advocate that digital games can provide positive effects for the elderly, with improvements in postural control, gait, cardiorespiratory fitness, and cognition. Similarly, digital games have also been used as a fitness training tool to improve balance and mobility (Santos, Guimarães, Matos *et al.*, 2015). Further, they have been also found to be a useful aid to generally improve the physical and functional abilities of the elderly required in everyday living activities (Raitoharju, Luimula, Pyae *et al.*, 2014). Also, Kattimeri, Qvist, Katajapuu *et al.* (2017) suggest that digital game-based exercises can be a useful choice for the elderly to

improve their physical activity and functioning. Mariann, Andrea, Anna *et al.* (2018) advocate that digital game-based balance training may be a preferable and safer intervention for the elderly to improve postural control whilst reducing the risk of fall. In the context of rehabilitation, Vasconcelos, Nunes, Carvalho *et al.* (2018) observe that serious games or digital games have become increasingly popular across a wide range of rehabilitative settings, including programs targeting improved balance and mobility, increased limb functionality, and also for general posture training.

In the digital game market, there is a number of commercial digital games in which players are required to use bodily movements as a form of exercise while playing the game. These games have attracted researchers' attention to use particularly for the elderly's physical fitness and rehabilitation. Since the introduction of the Nintendo Wii games in 2006, healthcare practitioners, researchers, and caregivers have become increasingly interested in using commercial digital games as a tool to promote the elderly's healthy and active lifestyle (Theng, Teo, & Truc, 2010). For instance, the Nintendo Wii Bowling game has been clinically used to decrease the fall risk for the elderly living in nursing homes (Clark & Kraemer, 2009). Although the existing literature shows the potential of digital games for the elderly's physical health, Boot, Moxley, Roque *et al.* (2018) point out that whilst digital gaming is a popular leisure activity for the general population, it has only a small number of elderly users. However, the authors state that with appropriate support and training, even the elderly with limited computer knowledge and experiences can participate in this activity and in some cases, become active players.

1.6 Research Gaps in Digital Game-based Physical Exercise Activity for the Elderly

Although the literature shows that digital games are promising to improve the elderly's physical well-being, digital games designed and catered for this age group is less understood and practised (Li, Erdt, Lee *et al.*, 2018). Also, research to date has highlighted that there are problems with them in terms of their applications for the elderly, specifically game usability, game design, and user experience. For instance, Brox, Konstantinidis, and Evertsen (2017) point out that most commercial games are not suited for the elderly due to their design not being targeted to that age group's skills and levels. These design flaws are observable in the elderly users' difficulty coping with the games' fast-paced speed, their difficulty in comprehending technical information supplied in user's manuals, and their difficulty in executing the fine motor skills

necessary to successfully complete the required hand and bodily movements on the controls. According to IJsselsteijn, Kort, and Poels (2017), most digital games in the market whilst promising as a tool to enhance the elderly's physical workouts; fail to deliver that promise fully because they are targeted to the younger players' skills and knowledge. Chia, Cheng, Hnin *et al.* (2018) also highlight that the majority of commercial games currently being marketed are, in terms of their technology, designed solely with younger users in mind, without any attention being given to elderly users' skill and knowledge base while lacking attention from an elderly perspective.

According to Palacio, Acosta, Cortez *et al.* (2017), in general, elderly users of products or services - due to age-related changes - face usability challenges. The authors also stress that products or services targeted to the elderly should have specific user-friendly features, more importantly, they should have useful applications, have built-in learning strategies to ensure ease of mastery, and they should effectively and efficiently deliver specific outcomes for the elderly user. Schell and Kaufman (2016) stress that in order to increase the uptake of digital games by the elderly, usability (ease of use) must be given priority. Sauvé, Renaud, Kaufman *et al.* (2015) highlight the commercial reality that the needs of the elderly demographic, for user-friendly technology is a vital consideration, at all stages of development, testing, and marketing of digital games to older users. In practical terms, this translates into a design informed by not only by the technical and design expertise of developers but also by the market knowledge of retailers and after-sales support and technical service personnel. The elderly will only adopt and enjoy the experiences available via these technologies if the games meet their requirements for a tool that is user-friendly, easy-to-use, and suited to their specific needs. They are more likely to take up and continue using these games in the long term if they come with those features built in.

Although the literature shows a rise in the number of studies being published, which focus on these features, Allaire, McLaughlin, Trujillo *et al.* (2013) point out that actual field research into the experiences of elderly digital games users is still limited. Kaufman, Sauvé, Renaud *et al.* (2016) suggest that future research into elder games users should have a dual focus to not only determine whether digital games are used effectively as an intervention to address age-related changes but also, just as importantly, to explore the nature and quality of their experiences whilst playing them. According to the existing literature, to date, there have been a number of scholarly publications that have investigated and reported user experiences, game design guidelines, and usability of digital game-based physical exercises for the elderly (Raitoharju, Luimula, Pyae *et al.*, 2014). However, Nawaz, Skjæret, Helbostad *et al.*

(2015) also caution that future studies should be carried out to produce quantifiable results and deeper insights into the usability of digital games for the elderly.

Specifically, in the context of Finland, the existing literature shows that there is a growing number of studies investigating the impact of digital games on the elderly's physical activity, rehabilitation, and cognitive abilities (Katajapuu, Granholm, Hiramatsu *et al.*, 2016). For instance, Kattimeri, Qvist, Katajapuu *et al.* (2017) conducted tests to determine the ease of use of digital games and the effectiveness of their application in the physical rehabilitation of elderly Finns, and they concluded that digital games are a promising tool for rehabilitative training for the elderly. Liukkonen, Mäkilä, Ahtosalo *et al.* (2015) designed and evaluated motion tracking exergames for elderly Finnish users, and their findings suggest the need for elder-friendly game design and game usability testing using a specialized game experience questionnaire tailored for the elderly. It should be noted that Finland is one of the countries involved in the *ACTIVAGE* project, in which Internet of Things (IoT) solutions are used for elderly Europeans to improve their quality of life and healthcare (ACTIVAGE, 2018). Another exemplar is *Business Ecosystems in Effective Exergaming* (BEE), which is a collaborative project between the Turku University of Applied Sciences and international collaborators in Singapore, Japan, and China (BEE, 2018). This BEE project aims at promoting the elderly's physical health through an effective exergaming system in different regions such as Europe and Asia.

Although there is a considerable number of previous and on-going studies in this general field of research; to the best of our knowledge, there is still only a limited number of investigations into elderly Finns' user experiences in playing digital game-based physical exercise activity, which includes both regular physical exercises and rehabilitation activities. Specifically, there is a limited study in terms of elderly Finns' attitudes, motivation, in-game and post-game experiences in playing digital game-based exercise activity. Further, there is only a small number of studies concerning usability challenges for the elderly Finns in utilising digital game-based physical exercise activity. Lastly, it is still unclear whether digital games can be used by elderly Finns as an alternative option for ways to participate in physical exercise and rehabilitation. In the previous section, we noted that there is a growing need in the health sector of Finland, for additional human resources, particularly therapists and caregivers both within retirement and aged care/nursing homes and home-based services for the elderly in their own residences. However, in this regard, it is still unknown how digital games can best be utilized to promote elderly Finns' physical rehabilitation and exercise activity in both nursing homes and home-based settings.

1.7 Research Questions

To fill the research gaps mentioned in the previous section, in this study, we conducted a research study of elderly Finns' experiences with a digital game-based exercise activity called the *Skiing Game* with the following research aims. Firstly, to investigate elderly Finns' user experiences in playing digital game-based physical exercise activity, we were particularly interested in investigating their attitudes towards digital games, in-game and post-game user experiences, and their motivation to use digital games for physical exercise activity. Secondly, to understand the usefulness of digital games for the elderly, we were interested in investigating whether digital games can be an alternative solution for them in doing physical exercises as well as rehabilitation activity. Thirdly, to investigate what challenges elderly Finns encountered with the use of digital game-based exercise activity, in terms of game usability, we were particularly interested in exploring game design, interaction, and usability problems. Based on these research aims, we formulated the following research questions for this study:

RQ1: What are the user experiences of elderly Finns in playing digital game-based physical exercise activity?

RQ2: What are elderly Finns' perceptions of playing digital games as an alternative way for undertaking a physical exercise activity?

RQ3: What are the usability challenges encountered by elderly Finns whilst engaged in a digital game-based physical exercise activity?

In this study, we also aimed at conducting a cross-country evaluation of digital game-based exercises with elderly users from a different cultural background. The main objective of the cross-country study is to investigate differences between elderly Finns' and elderly non-Finns' user experiences, specifically their perception of the usefulness, and usability of digital game-based physical exercise activity. Thus, we formulated the following research question for the cross-country evaluation: Table 1.1 shows the research questions and relevant chapters and publications.

RQ4: What are the differences in user experiences, usefulness, and usability of digital game-based physical exercise activity between the Finnish and non-Finnish elderly people?

Table 1.1 Research Questions, and Related Chapters and Publications

Research Question	**Chapter**	**Publications**
RQ1. What are the user experiences of elderly Finns in playing digital game-based physical exercise activity?	Chapter 3 – Methodology Chapter 4 – Requirements Gathering, Analysis, Design, and Prototyping Chapter 5 – Usability Studies Chapter 6- Publications Chapter 7 – Conclusion	Pyae, Raitoharju, Luimula *et al.* (2016) Pyae, Luimula, and Smed (2016) Pyae, Liukkonen, Luimula *et al.* (2017a) Pyae, Liukkonen, Luimula *et al.* (2017b)
RQ2. What are elderly Finns' perceptions of playing digital games as an alternative way for undertaking a physical exercise activity?	Chapter 3, 4, 5, 6, and 7	
RQ3. What are the usability challenges encountered by elderly Finns whilst engaged in a digital game-based physical exercise activity?	Chapter 3, 4, 5, 6, and 7	Pyae, Joelsson, Saarenpää *et al.* (2017)
RQ4. What are the differences in user experiences, usefulness, and usability of digital game-based physical exercise activity between the Finnish and non-Finnish elderly people?	Chapter 3, 4, 5, 6, and 7	Pyae, Joelsson, Saarenpää *et al.* (2017)

1.8 Significance of Research

Since authorities and researchers, particularly in Finland, are expanding the use of technologies to promote an improvement in the quality of life for the elderly in Finland (Katajapuu, Luimula, Theng *et al.*, 2017), the study findings can be useful for the Finnish healthcare practitioners and caregivers interested in using digital games as an alternative means of physical exercise for the elderly. Furthermore, if digital games can be effectively deployed in a clinical setting such as a physical therapy and rehabilitation unit within serviced homes for the elderly, it may help the Finnish authorities solve the problem of a labour shortage in the healthcare sector in Finland. The literature shows that it is important to promote independent living for elderly Finns, and the authorities are creating various services for the elderly to make their lives easier (e.g. living in their own homes for as long as possible). Hence, if elderly-friendly digital games can be deployed in elderly Finns' own homes, they can easily do home-based rehabilitation and exercises at times when for any reason, they cannot visit a clinical setting. To achieve

these objectives, it is important to investigate the perceptions of elderly Finns regarding their user experiences and to measure the reported usefulness of digital game-based exercises. This data will be insightful for designers and developers into digital games design and development best suited for the varying levels of physical fitness and rehabilitative needs of the elderly, and make adjustments to the technical specifications for the operation of the games to best match the age-related cognitive abilities and learning levels of the intended end-users – the elderly of Finland.

The study, although undertaken on a relatively modest scale, has produced significant research findings, which indicate that there is an unmet market for digital games for the elderly. This claim is also supported by previous studies, including Li, Li, Pham *et al.* (2018), Chia, Cheng, Hnin *et al.* (2018), Kattimeri, Qvist, Katajapuu *et al.* (2017), Nakai, Pyae, Luimula *et al.* (2015), and Cota and Ishitani (2014). The major contribution of this study is that it revealed key deficiencies in the design and operation of currently available commercial digital game-based physical exercises for the elderly; thus providing important guidelines to game designers, developers, and usability practitioners when designing new games. This study's findings are also highly relevant to healthcare practitioners, particularly in Finland, enabling them to gain useful insights into how to best use digital games to most efficiently and effectively promote the elderly's participation in physical exercise activities. In addition, it can also be useful for our future research in the respective fields of designing, testing, and marketing such products. Furthermore, the findings from this study can assist health policymakers in Finland gain clearer insights into the best strategies for introducing and implementing digital game-based programs for the elderly into the aged-care sector. Last but not least, the findings from the cross-country study will help us understand the user experiences of elderly non-Finnish people when playing digital game-based exercises, and it can create opportunities for the Finnish game companies to take into account how best to expand their customer base in an international market for their digital games with applications in both the public and private health sectors.

1.9 Gamified Solutions in Healthcare (GSH)

This thesis is a part of the *Gamified Solutions in Healthcare* (GSH) project, which is a collaborative research project between the University of Turku and Turku University of Applied Sciences in Finland, funded by *Business Finland* (formerly known as *Tekes*, Finland). In GSH, we collaborated with both industry partners such as GoodLife Technology and Puuha Group Finland, and with public sector organizations, including

the City of Turku, and *Attendo* Ltd. The international collaborators include the *Sendai City Health Promotion Center*, the *Sendai-Finland Wellbeing Center*, and *Sendai National College of Technology* in Japan. The core concept of GSH is the '*Virtual Nursing Home'*, which includes four gamified services for the elderly in Finland: *Rehabilitation*, *Socialization*, *Entertainment*, and *Counselling*. In this thesis, we focus on the Rehabilitation service, which provides digital game-based solutions to promote the elderly's physical exercise and rehabilitation. The main objectives of the Rehabilitation service are 1) to design and develop digital game-based exercises to promote elderly Finns' engagement in regular physical exercises and 2) to help elderly Finns with physical disabilities to engage in game-based training for physical rehabilitation.

There are three major stages in GSH: pre-studies for requirements gathering, prototyping, and evaluation. For the evaluation stage, we aimed at undertaking usability testing with elderly Finns to investigate their user experiences in playing digital game-based exercises. We also aimed at conducting cross-country usability testing with the non-Finnish elderly outside of Finland to investigate whether there are any differences in user experiences between elderly Finns and elderly non-Finns whilst playing digital game-based exercises, as well as to understand whether digital games designed for elderly Finns are accepted by the elderly non-Finns from a different cultural background. According to the United Nations (2015), Japan is one of the countries in the world with the highest ageing population. It should also be noted that the Japanese government has used modern technologies offering innovative approaches to ease the increasing burden of aged care (Dethlefs & Martin, 2006). Specifically, healthcare practitioners and researchers in Japan have used digital games, as part of their inventory of chosen technologies, to promote the elderly's well-being (Katajapuu, Granholm, Hiramatsu *et al.*, 2016). The similar demographic changes and challenges faced by both Finland and Japan prompted us to conduct a study in Japan into how effectively and efficiently digital game-based physical exercises have increased the elderly's participation in physical exercise activities. Hence, in this study, we collaborated with our Japanese counterparts: the *Sendai City Health Promotion Center* and the *Sendai-Finland Wellbeing Center* in Japan, and *Sendai National College of Technology* to conduct the cross-country usability study of the *Skiing Game.* In addition to Japan, we also aimed at conducting usability testing with elderly participants in Singapore to assess their experiences as users of digital game-based exercises (Katajapuu, Luimula, Theng *et al.*, 2017; Li, Xu, Tan *et al.*, 2017). In the GSH project, the author involved in requirements gathering or pre-studies such as the usability testing of commercial games, interviews, and observations at elderly homes in Finland. Also, the

author participated in analysis and design that includes mapping existing games, testing of different game consoles and devices, brainstorming, and designing game prototypes. In the functional prototyping of the game system, the author involved in the project as a research consultant, and interaction designer. In the Finnish usability testing of the *Skiing Game*, the author participated as the main researcher and conducted study preparation, data collection, data analysis, and manuscript preparation. In the Japanese usability study, the author participated as a research consultant, methodology, data collection, analysis, and manuscript preparation.

1.10 Study Design

The study has four stages: requirements gathering, analysis and design, prototyping, and evaluation. For requirements gathering, we conducted a number of pre-studies to collect data on the Finnish elderly's requirements whilst participating in physical exercises as well as rehabilitation training (specifically their reported problems and needs). We also reviewed the existing literature regarding digital games utilised for promoting the elderly's participation in physical exercises and rehabilitation. In addition, the usability and usefulness of existing commercial games and technologies were evaluated for their suitability for the elderly. The findings from the pre-studies were then analyzed for the purpose of designing digital game-based exercises for the elderly. We also discussed with healthcare professionals (e.g. nurses and therapists) to ensure the design ideas we made are suitable and user-friendly for the elderly. We conducted a number of iterations in this stage. For the prototyping stage, a functional game-based physical exercise activity system called the *Skiing Game* for the elderly was designed and developed. In this stage, we also consulted with design experts and healthcare professionals regarding the relevance of the game design for the elderly. Lastly, the game system was evaluated using two groups of elderly participants: a cohort of Finns living in Finland, and a cohort of non-Finnish ethnicity living outside of Finland. Figure 1.1 illustrates the different stages of the study. The following Table 1.2 shows the publications related to each stage of the study.

Figure 1.1 Four Stages of the Study

Table 1.2 Study Stages and Related Publications

Study Stage	**Publications**
Requirements Gathering	I. Pyae, Raitoharju, Luimula *et al.* (2016) II. Pyae, Mika, and Smed (2015) III. Pyae, Luimula, and Smed (2016)
Analysis and Design	IV. Pyae, Liukkonen, Saarenp *et al.* (2016) V. Pyae, Liukkonen, Luimula *et al*. (2017a) VI. Pyae, Liukkonen, Luimula *et al.* (2017b) VII. Pyae, Joelsson, Saarenpää *et al.* (2017)
Prototyping	
Evaluation	

1.11 Structure of Thesis

The thesis comprises seven chapters and the reprints of the research publications. Chapter 2 outlines the literature review, related studies, limitations of existing studies, and justifications for the use of the research questions formulated in this study. Chapter 3 outlines the research methodology, design, and procedures of the study. Chapter 4 outlines the pre-studies, analysis and design, and prototyping of the *Skiing Game*. Chapter 5 outlines the usability evaluation of the *Skiing Game* with both the Finnish and Japanese elderly participants in Finland and Japan respectively. Chapter 6 summarises the research publications resulting from the study. Chapter 7 outlines the concluding remarks of the study, the research implications, and limitations of the study. Lastly, we include the reprints of the research articles that we have published in peer-reviewed journals and conferences.

1.12 Summary

This chapter discussed the challenges of population ageing, and highlighted the importance of physical exercises for the elderly to enable them to live independently in old age. The literature relevant to the potential of digital games for the purposes of promoting the elderly's participation in physical exercise and rehabilitation was summarised, and the research gaps in this area were identified. The research questions of the study were then formulated, followed by the introduction to the parameters of the GSH project. We then described the significance of the study and the different stages of designing the study. Lastly, we outlined the structure of the thesis and provided an overview of the resulting research publications completed during the course of this project.

Chapter 2

Background

This chapter covers firstly a review of the literature on the benefits of utilising digital games for the elderly's physical well-being in rehabilitation and physical fitness training. Secondly, it assesses the different modes of digital game technologies for the elderly's physical rehabilitation such as virtual reality, augmented reality, and multimodal input devices. Thirdly, it reviews commercially available games for the elderly's physical exercise activity, including Nintendo Wii and Microsoft Kinect games. Fourthly, it states the research gaps by highlighting the existing problems and challenges encountered by elderly users of digital games. Fifthly, it clearly sets out the justifications for how the research questions were formulated for this study.

2.1 Digital Games for the Elderly's Physical Benefits

Digital games today are no longer seen as a leisure activity only for teenagers or young children, and players of digital games have extended beyond young adults, teenagers, and children (Wang & Sun, 2016). The elderly are now included amongst the newer potential players of digital games. For instance, Loos and Kaufman (2018) quantified the rise in elderly users of digital games and noted that in 2016, 26% of digital game players in the USA were aged 50 years and above (ESA, 2016). Furthermore, for over a decade now, the use of digital games by this cohort has also become a topic of increasing interest to researchers across a broadening range of disciplines including computer science and gerontechnology (Brian & Dwayne, 2015). According to the Entertainment Software Association of Canada (2012), digital games' ability to engage and immerse players in gameplay appeals not only to younger people but also to the elderly.

Li, Xu, Tan *et al.* (2017) state that although digital games were originally designed for entertainment purpose, they have been increasingly promoted for players' health benefits. Garcia and Lara (2018) state that engagement with digital games has shown positive results for the elderly when used for physical exercise and rehabilitation. According to Palacio, Acosta, Cortez *et al.* (2017), because playing digital games reinforces abilities and skills such as concentration, memory, coordination, and reaction speed, they can be beneficial for players particularly the elderly, as evidenced by improvements in their cognitive and physical functions. Researchers have argued that the use of digital games by the elderly can improve their cognitive abilities, social connectivity, and psychological well-being (Ferguson, Nielsen, & Maguire, 2017). Barg-

Walkow, Harrington, Mitzner *et al.* (2017) also claim that digital games have become a new delivery mode for leisure activities because health service providers (both private and public) can see the benefits of using digital game-based activities in terms of improvements in physical, social, and cognitive well-being specifically for the elderly.

According to Li, Theng, Foo *et al.* (2017), compared with traditional physical exercise intervention, digital game designs generally incorporate motivational features such as visual and audio-based feedback, which ensure the exercise activities are more interactive, and thus enjoyable, and even meaningful. Digital games, currently available in the market, are basically designed to be enjoyable, challenging, and capable of sustaining player's engagement (Chesham, Wyss, Müri *et al.*, 2017b). With the help of motivating and fun-based game elements, digital games have increased in popularity amongst the elderly since the release of Nintendo Wii, which introduced a revolutionary interactive design where users execute real-time physical movements to mirror the real limb and torso movements of the actual sport. The attraction was that instead of being played on a court or field, it is played in a digital mode in their own home or at rehabilitation or healthcare or aged-care venue (Theng, Teo, & Truc, 2010). According to Kappen, Mirza-Babaei, and Nacke (2018), various descriptors have been used by researchers to categorize the benefits to the elderly users of digital games in terms of their levels of physical activity, fun, and exercise The terminology employed includes game-based exercising, embodied interactive games, and exertion games. The concept of digital game-based physical exercises for the elderly has also called for the development of new labels and classifications specific to these non-entertainment applications of digital games, such as serious games for healthcare (Tashiro, 2009), exergames (Brox, Evertsen, Åsheim-Olsen *et al.*, 2014), gamification for healthcare (Brauner, Calero Valdez, Schroeder *et al.*, 2013), and games for health (Baranowski, Blumberg, Buday *et al.*, 2016).

The existing literature also shows that healthcare professionals, practitioners, and researchers have given due regard to the as yet unrealised full potential of digital games for improving the physical health and rehabilitation of the elderly (Kato, 2010). Digital games have so far been successfully used to improve the physical well-being of the elderly as witnessed by their increased engagement and participation in regular exercise routines (Taylor, McCormick, Shawis *et al.*, 2011), rehabilitation (Pyae, Tan, & Gossage, 2013d), and by such tangible outcomes as improved rates of fall prevention (Santos, Guimarães, Matos *et al.*, 2015). Oesch, Kool, Fernandez-Luque *et al.* (2017) conclude that digital game-based exercises are an attractive alternative for increasing the motivation of the elderly to participate in self-regulated exercises. Wüest, Borghese,

Pirovano *et al.* (2014) state that digital games are the most practical and effective in the context of rehabilitation when they have been specifically designed for use by the elderly for therapeutic purposes. According to the literature, healthcare professionals and researchers have incorporated both commercial games (e.g. Nintendo Wii and Microsoft Kinect for Xbox), and in-house games designed specifically for elderly participants in physical exercise and rehabilitation programs. In the next section, we will review and discuss how digital games have been used to improve the elderly's physical well-being and we will discuss the benefits of these tools.

2.1.1 Digital Games for the Elderly's Physical Activity

The literature shows that digital games have been used for purposes other than rehabilitation, such as to promote the general physical well-being and activity of the elderly. Chao, Scherer, and Montgomery (2015) conducted a review of 22 empirical studies of digital games, which had been used to enhance the physical function of the elderly and concluded that using digital games (e.g. Microsoft Kinect Sports games and Nintendo Wii exergames) shows much promise as an intervention to improve the physical function, cognition, and psychosocial well-being of the elderly. Kaufman, Sauvé, Renaud *et al.* (2016) recruited 463 adults aged 55 years and above from senior centers and shopping malls in Canada and conducted a survey of their gameplay experiences. The results of their study show that the use of digital games can provide innovative and engaging activities for enhancing the elderly's lives and offsetting the negative aspects of the ageing process.

To date, there are a number of academic investigations into the positive impacts of digital games on the elderly's physical well-being. These include research into the use of digital games by the elderly for physical therapy (e.g. stroke rehabilitation), functional tasks (e.g. game-based driver training), tasks to enhance daily living (e.g. ADL training), and recreational activities (e.g. playing games). For instance, a VR-based game system is used to enable the elderly to drive in a virtual environment (Hämäläinen, Rashid Izullah, Koivisto *et al.*, 2018). Sue, Ray, Talaei-Khoei *et al.* (2014) also designed for the elderly a game-based driving activity to improve the necessary physical functions and cognitive competencies. Luimula, Besz, Pitkäkangas *et al.* (2015) also designed and implemented a virtual game-based evaluation tool to better deliver driver training, as well as testing targeted to a range of user groups including the elderly. Their studies show the potential of a digital game-based system for driver training in old age. The authors also suggest

that the low cost of the VR-technology-aided virtual driving environment may be useful for the elderly (Luimula, Besz, Pitkäkangas *et al.*, 2015).

In the existing research, digital games have also been used for different purposes to engage the elderly with physical activity. For instance, Pyae, Tan, and Gossage (2013d) designed and developed a digital game-based activity system for the elderly in Singapore to train them in skills required for various tasks daily life (ADLs) skills. According to Neumann, Meidert, Barberà-Guillem *et al.* (2018), digital games with activity-focused physical training relevant to the ADLs of the elderly can improve their individual fitness status. Vallejo, Wyss, Chesham *et al.* (2017) also developed a virtual cooking game as a multitasking tool to assess the physical condition and ADLs of the elderly. Rusu, Mocanu, S *et al.* (2016) implemented a digital game-based training aid to achieve ADLs required by the elderly, delivered through physical activity. Their studies show that digital game-based physical training can achieve improvements in the physical condition of elderly users if they practice regularly. It is important to note that digital games have also been used by the elderly for recreational purposes. For instance, Kahlbaugh, Sperandio, Carlson *et al.* (2011) used the Nintendo Wii's Bowling game as a form of recreational activity to promote the enjoyment and social connectivity of the elderly. Aarhus, Grönvall, Larsen *et al.* (2011) used digital games to motivate and engage the elderly in physical exercise activities. Based on the literature, we claim that digital games are promising to promote the elderly's physical activity and improve their motivation to engage in such activity over the long term.

2.1.2 Digital Games for the Elderly's Physical Rehabilitation

As a consequence of the evolution of digital game technologies, the use of digital games has become especially popular in the field of rehabilitation of the elderly, as well as of younger age groups who were usually the major clients (Bruno, Mélissa, Bart *et al.*, 2017). According to Alana, Pascal, Veronica *et al.* (2015), in the past few years, the introduction into the rehabilitation process of interactive digital technology has positively shaped traditional intervention. Ravyse, Tarkkanen, Blignaut *et al.* (2017) state that digital games for rehabilitation can provide therapeutic benefits in three treatment categories: musculoskeletal, neurological, and general health, for conditions such as acute hypertension and heightened cholesterol. Tarkkanen, Ravyse, Katajapuu *et al.* (2018) conclude that players' reported positive experiences and perceived and measured beneficial outcomes arising from the use of rehabilitative games go beyond

general physiological benefits but have also been found to specifically heighten individuals' motivation to remain engaged with their rehabilitative program.

Sato, Kuroki, Saiki *et al.* (2014) point out that low rates of long term engagement and sustained interest in physical exercise programs are a common problem amongst elderly participants. Lohse, Shirzad, Verster *et al.* (2013) highlight as a major concern for rehabilitation professionals is that patients are not meeting the required number and type of physical movements to induce the necessary neuroplastic adaptations. These adaptations are crucial underlying enablers of behavioural improvements. To overcome this problem, digital games have been used by fitness and health professionals as a tool to motivate the elderly to regularly participate in physical exercises (Katajapuu, Luimula, Theng *et al.*, 2017). Digital game-based exercises that encourage players' physical mobility are promising to keep the elderly active and committed to a regular exercise routine (Chia, Cheng, Hnin *et al.*, 2018). According to the literature, there is a growing variety of digital games with either potential or already established applications for a range of rehabilitative purposes. Specifically, there are serious games, exergames, virtual reality, and augmented reality games useful for application in the rehabilitation of elderly patients with motor deficits. Research on each of these is summarised in the following sections.

2.1.3 Serious Games for Physical Rehabilitation

According to Michael and Chen (2005, p. 17), a '*Serious Game*' is defined as "*a game in which education (in its various forms) is the primary goal, rather than entertainment*". Rego, Moreira, and Reis (2010) further categorise serious games to include any game genre, technology, or platform, which teaches players to develop skills. The term '*Serious Games*' is widely used today to describe digital games whose primary purpose is not for entertainment, but for education and training (Proença, Quaresma, & Vieira, 2018). The use of this concept has been noted in various fields, including health and rehabilitation. In recent years, a new generation of games requiring players, to move their body as part of an interactive system has been designed and marketed. These emerging applications can greatly aid the elderly to either improve their ongoing engagement in health-related physical activities, or improve their sensory-motor coordination, or increase their motivation (Wiemeyer & Kliem, 2012). According to Rego, Moreira, and Reis (2010), traditional interventions for physical rehabilitation include exercises that are often considered by elderly patients to be repetitive and boring. Incorporating digital games with a serious purpose into the physical and

cognitive training tailored for elderly clients with physical disabilities offers significant therapeutic benefits. Gobron, Zannini, Wenk *et al.* (2015) confirm that serious games can transform tedious and repetitive conventional therapeutic exercises into an enjoyable and motivating activity, by engaging users in a meaningful game, or transporting them into a virtual world. Rego, Moreira, Lu *et al.* (2014) contend that serious games can distract elderly patients from their disability, through an absorbing game story and relatable characters. Combined with challenging motor and cognitive activities, constant feedback, varying levels of difficulty and challenges, and other entertaining elements such as realistic sounds and colourful graphics these design and operational features ensure motivation to continue using the digital tool is maintained.

Hocine, Gouaïch, Cerri *et al.* (2015) propose a digital game adaption technique, which seeks to improve the therapeutic outcomes for stroke patients including the elderly. They implemented three versions of a serious game for upper-limb rehabilitation, followed by participant evaluation by seven stroke patients and three therapists. Their findings concluded that the dynamic adaption technique of serious games can increase movement amplitude during patients' therapeutic sessions. According to Pisan, Marin, and Navarro (2013), falls by the elderly are one of the leading causes of injury and disability amongst this age group. Whilst the authors point out that physical exercises can reduce by 40% the potential risk of falling, the exercise adherence rate of elderly patients is low. Therefore, they designed and evaluated a digital game-based fall prevention training program in collaboration with the elderly (Pisan, Marin, & Navarro, 2013). Their findings suggest that using game-like exercises with the elderly can result in an increased rate of adherence to a physical exercise routine. There are a significant number of studies of the rehabilitative use by the elderly of serious games for balance training (Betker, Desai, Nett *et al.*, 2007), stroke rehabilitation (Hocine, Gouaïch, Cerri *et al.*, 2015), neurorehabilitation (Wiemeyer, 2014), and other applications (Lope & Medina-Medina, 2017).

2.1.4 Exergames for Physical Rehabilitation

'*Exergames*' that represents a genre of gaming for fitness has gained popularity among players (Kappen, Mirza-Babaei, & Nacke, 2018). Sinclair, Hingston, and Masek (2007, p. 1), simply define '*Exergames*' as "*the use of video games in an exercise activity*". Oh and Yang (2010, p. 10) further describe the genre as "*an experiential activity in which playing an exergame or a video game requires physical exertion or movements that are more taxing than sedentary activities*" and *" [build] strength, balance, and flexibility*".

Pirovano et al. (2016, p. 56) also state that "*a therapeutic exergame is [one which] supports all primary and secondary goals defined for an exercise*".

Exergames can be an attractive alternative way to motivate the elderly to perform self-regulated exercises. They are prescribed in addition to supervised therapeutic sessions (Oesch, Kool, Fernandez-Luque *et al.*, 2017). Exergames are a combination of exertion and entertainment for players whilst engaging in physical exercise. To control the game whilst exergaming, players perform physical exercises designed to promote an active lifestyle through persuasive technology (Rendon, Lohman, Thorpe *et al.*, 2012). Basically, exergaming can make physical exercise activities more appealing. Its biggest advantage is its capability of engaging a large audience of various decades in an ageing population (Lieberman, Chamberlin, Medina *et al.*, 2011). According to Skjæret, Nawaz, Morat *et al.* (2016), there is a growing interest in exergames as a promising rehabilitation tool to facilitate specific exercises targeted at different clinical groups. The authors also describe how exergames can promote elderly users' improvements in mobility, muscular strength of the lower limbs, balance control, and cognition. Sato, Kuroki, Saiki *et al.* (2014) describe exergames, involving the elderly in exercise activities, as an intervention to promote regular exercise. They note that such use resulted in demonstrated improvements in balance, mobility, and physical exercise performance. Laver, Lange, George *et al.* (2017) suggest that exergame-based intervention with the elderly is a promising approach for stroke recovery.

Lange, Requejo, Flynn *et al.* (2010) highlight the fundamental advantages of exergames compared with traditional exercises. They explain these advantages arise from exergames' capability to deliver to elderly patients task-specific exercises, which offer a range of levels of difficulty. In addition, the individual player can begin at an age- and skill-appropriate level that is realistic, achievable, and comfortable, then, a gradual progression of increasing difficulty can be introduced, based on the individual's performance in real-time. According to Ramírez, Duncan, Brebner *et al.* (2017), successful stroke rehabilitation greatly relies on long-term and intensive treatment. However, such a regime is rarely adhered to by patients. , The advantage of exergames is their potential to increase elderly patients' engagement with their therapy. Sato, Kuroki, Saiki *et al.* (2014) designed and developed an exergame that uses the Microsoft Kinect sensor, then conducted a randomized controlled experiment of the effects of exergames on muscle strength and balance in healthy elderly people. Their findings show that the Kinect-based exergame was effective with elderly participants in improving their walking gait, muscular strength, and balance. Wüest, Borghese, Pirovano *et al.* (2014) conducted an experiment on elderly subjects to assess the usability and effects of

exergames on their balance and gait. Their findings showed exergame-based intervention improved physical performance, as measured by gait and balance. Although the literature shows the potential of exergames as a promising intervention to improve physical function in the elderly, further research is required in order to effectively and successfully establish exergames as an established mainstream exercise and rehabilitation tool for the elderly (Skjæret, Nawaz, Morat *et al.*, 2016, p. 5).

2.1.5 Gamification for Physical Rehabilitation

'*Gamification'* is '*the use of game design elements in non-game contexts*' (Deterding, Dixon, Khaled *et al.*, 2011, p. 10). Altmeyer, Lessel, and Krüger (2018, p. 1) give this further definition: "*Gamification, [is] the use of game elements in non-game contexts, [to] successfully motivate people to reach their goals more efficiently, or turn unpleasant tasks into fun ones*". Korn, Funk, and Schmidt (2015, p. 1) also state that "*using video game elements to improve user experience and user engagement in non-game applications is called gamification*". In the last few years, gamification has been used as an effective approach to improve people's motivation and performance whilst completing a range of activities (Hervas, Ruiz-Carrasco, Mondejar *et al.*, 2017). Theng, Lee, Patinadan *et al.* (2015) state that the basic idea of gamification is to make an activity or a task feel more like a game, encouraging users or players to engage in that activity and to achieve the desired outcomes. For instance, it has been used in different contexts including education, entertainment, health, and business. Edwards, Lumsden, Rivas *et al.* (2016) note that gamification can be an effective means for users to promote and sustain healthy behaviours, tapping into playful and goal-oriented aspects of human nature. According to Cafazzo, Casselman, Hamming *et al.* (2012), there are successful gamified health applications in the market (e.g. Nintendo Wii). The types of game strategies used in gamified systems are key to how successfully users' health behaviours change over time whilst engaged in a particular activity. The most effective strategies incorporate the setting of goals, provision of feedback on performance, delivery of reinforcement, graphic displays of the user's comparative rates of progress - both over time and also in relation to other users - and promotion of greater social connectivity. For more than a decade, researchers, as well as health and fitness practitioners, have used the gamified system to promote the elderly's physical, social, and cognitive well-being. Their findings, as detailed above, speak eloquently of the benefits of this system for this particular age group.

According to Rachel (2016, p. 1), gamification for rehabilitation goes beyond simply creating a fun and exciting application in which to complete rehabilitation exercises and interventions. The authors explain that "*gamification of rehabilitation means capitalizing on the concept of autonomy, as well as other aspects of engagement and motivation*". During the past few decades, gamification and gamified systems have been mostly seen in the context of health and exercise and gameful systems for exercise have been developed extensively (Matallaoui, Koivisto, Hamari *et al.*, 2017). For instance, Katajapuu, Luimula, Theng *et al.* (2017) designed and implemented gamified exercise programs for elderly Finns and they also evaluated the games with elderly subjects in both Finland and Singapore. Their findings confirmed that gamified exercise programs were beneficial to the elderly participants engaged in physical exercise training, particularly those undergoing physical rehabilitation. Raitoharju, Luimula, Pyae *et al.* (2014) also describe the potential of gamified solutions to promote physical activity in Finland specifically amongst elderly Finns. Kattimeri, Qvist, Katajapuu *et al.* (2017) conducted a cross-country testing of the usability of gamified healthcare systems for the elderly in Finland and Asia. Their findings also suggest that gamified exercises for the elderly have proven successful in increasing the engagement of the elderly in regular physical exercise. In Singapore, Ascolese, Kiat, Pannese *et al.* (2016) designed a digital gamified solution to promote active ageing and the findings from their study show the potential benefits of digital gamified medical games for the elderly. There is currently available a significant body of research into the gamification approach to physical rehabilitation of the elderly, and this literature confirms the promotion of a gamified approach to the elderly's physical rehabilitation has proven benefits.

2.1.6 Games for Health in Physical Rehabilitation

According to Hall, Stellefson, and Bernhardt (2012), the widespread access to, and use of, modern technologies has sparked the growth of digital tools as innovative solutions to promote engagement of the elderly in healthcare activities. Marston, Freeman, Bishop *et al.* (2016) conclude that there is a growing interest by the elderly in the use of digital game technologies, and a growing uptake of these technologies across a wide range of disciplines, from professionals with expertise in ageing and gerontology to those involved in computer science and gaming studies. In the last few decades, digital games have emerged as a valuable aid for effective health promotion and intervention programs for various age groups including the elderly. '*Games for Health'* are distinguished by "*utilizing gaming strategy to change people's health behaviours*". '*Games*

for Health' are utilised across a wide range of applications from preventative and therapeutic programs, to evaluative assessment teams, and units tasked with education and training, or organisations involved in designing informatics, and commercial entities involved in game production (Hall & Marston, 2016). According to Games for Health Europe (2018), '*Games for Health*' can be more cogently defined as the use of digital games and game-based strategy (e.g. gamification) in a health setting tasked with the delivery of healthcare. Baranowski, Blumberg, Buday *et al.* (2016, p. 1) note that "*digital games for health (G4H) offer exciting, innovative, potentially highly effective methods for increasing knowledge, delivering persuasive messages, changing behaviours, and influencing health outcomes*". Lu and Kharrazi (2018) conclude that in recent decades, digital games and gaming technologies have been designed and used to improve people's health and ensure more efficient and effective delivery of healthcare. Ricciardi and De Paolis (2014) highlight the finding that games for health have been regarded as a powerful tool of learning and skills development for health professionals. In recent decades, digital games have been used to promote the physical health of the elderly and to improve the delivery of their healthcare (Raitoharju, Luimula, Pyae *et al.*, 2014). Xu, Li, Pham *et al.* (2016) note that digital games have been used to promote healthy and active ageing and a significant body of research has shown the positive impact of digital games on the elderly's health, particularly their physical and social well-being. The literature also shows that there is a growing number of studies using digital games for health and healthcare purposes especially for the physical rehabilitation, cognitive well-being, and social connectivity of the elderly (Pyae, 2018).

2.1.7 Virtual Reality Games for Physical Rehabilitation

The use of Virtual Reality (VR) technology in the form of digital games as a complementary tool for rehabilitation programs is of increasing interest to those involved in both research and clinical practice (Molina, Ricci, de Moraes *et al.*, 2014b, p. 1). VR is defined as "*the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear and feel similar to real-world objects and events*" (Weiss, Kizony, Feintuch *et al.*, 2006, p. 183). According to the Virtual Reality Society (2017, p. 1), VR is "*the creation of a virtual environment presented to our senses in such a way that we experience it as if we were really there. It uses a host of technologies to achieve this goal and is a technically complex feat that has to account for our perception and cognition. It has both entertainment and serious uses*". Cho, Lee, and Song (2012) note that VR involves computer-generated

interactive simulation, which controls the information delivered to sensory organs to provide a virtual environment and to make players think imaginary objects and incidents are real. According to Weiss, Rand, Katz *et al.* (2004), in a virtual world, players conduct tasks (e.g. walking and moving objects), which feel very much like real-world experience. Sherman and Craig (2018) state that VR technology can be grouped into three paradigms: head-based, stationary-based, and hand-based. For head-based VR, people use either a head-mounted display or helmet or glasses onto which 3D graphic images are displayed. Users can use additional input devices such as a position-tracking sensor, a game controller, an interactive glove, or a voice activation device. For stationary-based VR, users do not need to wear or carry VR hardware on their person, instead of the device can be fixed to any object within the health service provider's facility, or the user's own game room/physical space. In this type of VR technology, projectors or large display screens are used to display the visual information. Hand-based VR is a type of hardware including smart-phones and tablets which users hold in their hands

In the context of physical rehabilitation, different types of VR technology have been used for many years. According to Laver, Lange, George *et al.* (2017, p. 5), VR-based games have recently emerged as a treatment approach for the rehabilitation of stroke patients. In the past decade, the use of VR for stroke rehabilitation has attracted considerable attention from researchers (Burdea, 2003). Lohse, Hilderman, Cheung *et al.* (2014) describe how VR-based therapies appeal to researchers because they can provide patients and therapists with additional feedback during therapy sessions, allowing them to increase patients' motivation, and dynamically adjust the level of difficulty for the user whilst in therapy. According to Molina et al. (2014b), existing studies suggest that VR-based exercises can promote the elderly's overall physical health, by improving mobility, muscular strength, balance control, reaction time, and can also be used in fall-prevention interventions.

By way of illustration, a team of Finnish researchers designed and developed a head-based gamified VR system called '*Hole in the World*'. This game both enabled elderly patients to exercise and allowed therapists to keep track of their patient's progress in real-time during therapeutic training (Kravat, 2018). Cho, Hwangbo, and Shin (2014) used station-based VR training for the elderly to determine the effects of VR games on their balance. The findings suggest that VR-based training not only effectively improved the balance of elderly users but also successfully operated as a fall prevention exercise. Park, Kim, and Lee (2015) further examined the effects of general ball exercises on the balance abilities of the elderly by comparing stationary-based VR ball

exercise. The findings from their comparative study across several communities show that VR-based games may improve balance and gait of the elderly Giesbrecht, Miller, Jin *et al.* (2015) state that alternative approaches such as mobile-based healthcare services and eLearning have become a necessity for the efficient delivery of effective rehabilitation services. The authors developed a table-based VR system (hand-based) for wheelchair training for older adults and evaluated the feasibility of such a system. Based on the existing literature, VR based games have been shown to offer significant potential benefits for the physical rehabilitation of the elderly.

2.1.8 Augmented Reality Games for Physical Rehabilitation

In recent years, Augmented Reality (AR) has created opportunities for research into the use of AR-based games to deliver physical rehabilitation services to the elderly. Sucar, Azcárate, Leder *et al.* (2009) comment upon the use of AR technology in rehabilitation to the extent that in the last decade AR has become the new paradigm for research into assistive technology. According to Sherman and Craig (2018, p. 23), AR can be defined as "*a medium in which real-time interactive digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world*". Peddie (2017) states that there are three ways to present an ARvisual: see-through, obstructed view, and projected augmented reality. A visual-see-through AR is a key method of creating AR technology through either contact lenses, or smart-glasses, or via a helmet, or a head-up display. In visual-see-through AR, users' perception of the real world is either unmodified or restricted and it displays the information and/or graphics as an overlay by means of transparent displays (Peddie, 2017, p. 7). For the obstructed view in AR, users wear a head-mounted display (HMD), which is fed a view of the real-world from a front camera integrated into the HMD. In this system, the augmented information or graphics are blended into the video feed of the real-world. For the projected augmented reality, it overlays information and graphics projected from the headset or HD out onto the real-world environment and onto physical objects.

Sousa, Vieira, Medeiros *et al.* (2016) state that AR-based digital games have shown significant potential and can be a highly valuable aid to rehabilitation when combined with carefully designed and customized feedback mechanisms. Burke, McNeill, Charles *et al.* (2010) further describe how AR games have the potential to deliver interesting and rewarding therapeutic outcomes for upper limb stroke rehabilitation. Kurz, Fedosov, Diewald *et al.* (2014) conducted a field test with a head-mounted display AR system and tablet computers for elderly users and the authors

suggest that for the elderly, the use of lightweight head-mounted displays are more suitable than hand-held tablets in meeting their need for mobility and independence.

Yamamoto, Hyry, Krichenbauer *et al.* (2015) designed and developed a projection tabletop system as a novel assistive tool for the elderly. It aimed to improve the quality of their lives by letting them manage their own daily activities. Sousa, Vieira, Medeiros *et al.* (2016) designed an intelligent user interface using AR technology called '*SleeveAR*', which is a novel approach providing real-time interactive feedback, allowing patients to perform rehabilitation exercises by themselves under the offline supervision of a therapist. The findings from their experiment show that the AR-based system can successfully guide patients through an exercise prescribed by therapists, with resulting improvements in performance. Zhang, Shen, Ong *et al.* (2010) designed a low-cost rehabilitation program for improved hand movements. It utilised AR technology and a wireless data-glove based on flex sensors and Bluetooth to make the intervention more entertaining and engaging for patients. When compared with traditional rehabilitation systems, they found the AR-based system costs less and is more engaging for patients. AR-based tasks have also been designed to facilitate the easier completion of daily activities at nursing homes in Singapore. Although the use of AR technology is relatively new compared with VR technology, there is an increasing number of studies carried out to investigate its comparative efficiency and effectiveness in achieving physical rehabilitation outcomes.

2.2 Commercial Digital Games for the Elderly's Physical Exercise Activity

For more than ten years, commercial games available in the market began to be used to improve the well-being of the elderly. The programs incorporating these games had a focus on enhancing elders' physical health (e.g. balance and mobility), cognitive skills (e.g. memory and cognition), as well as enhance their social connectedness (e.g. intergenerational games). These commercial games were selected because they showed promise as a means of engaging the elderly in physical exercises and activities in a way that made it a positive experience (TNO & VitaValley, 2017). According to Anguera and Gazzaley (2015), commercial games are designed to be enjoyable and challenging for players, as well as capable of sustaining players' engagement in the gameplay. These games include Nintendo Wii Sports games, Microsoft Xbox Fitness games, PlayStation Move games, Dance Dance Revolution, and other games, which used commercial game technologies such as Wii balance board, Microsoft Kinect motion sensor, and Dance pad.

In the next sections, we will review the commercial games for promoting the physical well-being of the elderly.

2.2.1 Nintendo Wii Games

The Nintendo Wii, which is a home-based video game console, was released in 2006. This novel interactive game system consists of exercise-based game software, the Wii console, and controllers such as the Wii Balance Board, Wii remote, and Nunchuk (Goble, Cone, & Fling, 2014). This game system includes both fun and fitness activities for all ages, including physical well-being (e.g. joint flexibility, muscle strength, and standing posture). Since it has been released, the Nintendo Wii has been well-accepted among both younger and older age groups. According to Brox, Evertsen, Åsheim-Olsen *et al.* (2014), the Nintendo Wii has been often used in senior centers due to its early entrance on the market for exergaming, which targets a larger audience. Jung, Li, Janissa *et al.* (2009) describe how Nintendo Wii has not only gained a huge commercial success but also amassed a huge success following among the older generations, dispelling the misconception that the elderly cannot keep up with technology. The authors also suggest that Wii games have the potential to address the health and well-being concerns of the elderly due to the substantial amount of physical activity required to play it. Nicholson, McKean, Lowe *et al.* (2015) point out that interactive gaming technologies such as the Nintendo Wii have been used as an effective tool to enhance elders' experiences in balance and mobility training. The authors also note that the Nintendo Wii game is relatively inexpensive and low-cost technology, which makes it an economical option for use in fall-prevention interventions for the elderly. Goble, Cone, and Fling (2014) report that the use of the Nintendo Wii Fit balance games as an intervention tool has shown positive balance outcomes, advocating their use for neurorehabilitative training. The existing literature shows that Nintendo Wii Fit games have been largely used for balance rehabilitation for the elderly (Montero-Alía, Muñoz-Ortiz, Jiménez-González *et al.*, 2016; Negrini, Bissolotti, Ferraris *et al.*, 2017). For instance, Negrini, Bissolotti, Ferraris *et al.* (2017) suggest that Nintendo Wii Fit can successfully aid the elderly to achieve functional improvements through balance training.

Bieryla and Dold (2013) investigated the feasibility of Nintendo Wii Fit games in delivering training to improve the clinical measures of balance in the elderly and to retain the improvements after some time. Their findings suggest that balance training with Nintendo Wii Fit can be a novel way for elders to improve their physical balance.

Chiang, Tsai, and Chen (2012) conducted an experimental study with institutionalized elderly participants, and their findings indicate that Microsoft Xbox 360 Kinect games show promise in improving this age cohort's eye-hand coordination and visual performance skills. Nicholson, McKean, Lowe *et al.* (2015) conducted an experiment to determine the effectiveness of unsupervised Nintendo Wii Fit balance training with the elderly. The findings from the six-week study show that unsupervised Wii balance training is an effective modality for improving balance in independent elderly people. Overall, Nintendo Wii exergames (e.g. Wii Sports and Wii Fit) have become popular in rehabilitation and long-term care settings (Chao, Scherer, & Montgomery, 2015). They have been increasingly used as an alternative solution to conventional rehabilitative exercises to improve the physical fitness of the elderly (Gil-Gómez, Lloréns, Alcañiz *et al.*, 2011).

2.2.2 Microsoft Kinect-Based Games

Microsoft Xbox Kinect, which is a video game platform, using motion sensors to track players' movements and provide visual feedback, has shown great potential to be used as a home-based tool for balance rehabilitation especially for the elderly (Beaulieu-Boire, Belzile-Lachapelle, Blanchette *et al.*, 2015). According to Saenz-de-Urturi and Garcia-Zapirain Soto (2016), the Microsoft Kinect is a motion sensor, which has sufficient accuracy for the assessment of whole-body kinematics for postural control and diagnostic purposes. Webster and Celik (2014) conclude that it is the most feasible technology for wide use by the elderly whilst exergaming because it can utilize motion-based data capture and requires no additional hardware (e.g. controller). Nakai, Pyae, Luimula *et al.* (2015) note that the Kinect system involves a motion detection sensor, which can instantaneously acquire data such as joint angles, and these Kinect-based exergames can be easily comprehended by elderly users who may have little or no previous experience in playing video games (Pyae, Liukkonen, Saarenp *et al.*, 2016). Marinelli and Rogers (2014) suggest that Microsoft Xbox 360 with Kinect games show promise for improving elderly users' engagement in sustained physical activity. The existing literature states that the Microsoft Kinect-based games are promising for use in fall detection (Alazrai, Momani, & Daoud, 2017) and fall prevention among the elderly (Choi, Guo, Kang *et al.*, 2017).

Beaulieu-Boire, Belzile-Lachapelle, Blanchette *et al.* (2015) also claim that one of the major components of fall prevention is balance training, which could be achieved using the Kinect-based rehabilitation system. The authors conducted a 10-week

program of balance training targeted to the elderly using Kinect, and their findings suggest that the Xbox Kinect games could be a great adjunct to a multidisciplinary treatment approach to improve balance. The observational study of the effects of the Kinect system on elderly users suggests that this system can provide a simple, reliable, and age-sensitive assessment of balance for elderly clients. They also recommended that the Kinect system is used as an alternative representation of both static and dynamic balance function in the elderly. The findings from the study by Garcia, Schoene, Lord *et al.* (2016) indicate that the Kinect-based step training program was safe and feasible for elderly clients to undertake unsupervised exercises at home, leading to improvements in stepping, standing balance, gait speed, and mobility. Keizo, Kaoru, Syuko *et al.* (2015) designed and developed a Kinect-based exergame to allow elderly users to engage in regular exercise at a low cost. The authors conducted a randomized controlled trial to investigate the effects of using this exergame on muscle strength and balance in the elderly. Their findings show that the Kinect-based exergame was effective in improving elders' walking muscular strength, and balance. Based on the literature, we can state that Microsoft Kinect games have been well-accepted among the elderly, especially for physical rehabilitation.

2.2.3 Other Commercial Games

There are other commercial digital games on the market, which have also shown their potential to be used as a tool to promote the elderly's physical well-being in general. For instance, Rand, Kizony, and Weiss (2008) used the Sony PlayStation II EyeToy as a low-intervention in the context of rehabilitation, and their findings show that VR based rehabilitation is an enjoyable way of doing therapeutic exercises for the older generation. The Dance Dance Revolution (DDR) game system was also used for in-house training of stepping ability for the elderly and has potential as a low-cost and engaging platform in rehabilitative training (Smith, Sherrington, Studenski *et al.*, 2011). Pyae, Mika, and Smed (2015) used the PlayStation II games and Move motion controllers as serious gaming for physical exercise activities with the elderly. The authors reported that the game system has drawn attention and interest from the elderly participants, but noted that the Move controller was assessed by them as not being older-user-friendly. Comunello and Mulargia (2017) proposed using the location-based Augmented Reality game called '*Pokémon Go*' to both improve intergenerational communication between the elderly and the young and to promote greater physical activity across all age groups. Other than Nintendo Wii and Microsoft Xbox games, the literature shows there has been

a little investigation into the use of other commercial games for increasing participation by the elderly in physical exercise and activities.

2.2.4 Game Controllers for the Elderly

Game controllers play a vital role for players to interact with game systems. To date, there are a number of multimodal input devices for digital games, including controller-based input devices (e.g. Nintendo Wii, PS3 controller, Xbox controller, and PlayStation PlayMove controller), motion-based controllers (e.g. Microsoft Kinect, Leap Motion, and Extreme Reality), touch-based controllers (e.g. smartphones and tablets), and brain interaction devices (e.g. Emotive). In addition, there are commercial game controllers or interactive multimodal input devices such as Nintendo Wii remote, controller, Nunchuk and balance board, Sony PlayStation's EyeToy, Dance pad (e.g. Dance Dance Revolution), sensor-based input (e.g. RFID), and OptiTrack Motion Capture System. Of these interactive game controllers, Nintendo Wii Remote, Balance Board, and Nunchuk have drawn attention from researchers for use in improving the participation of the elderly in physical exercise and activities, according to the studies by Gil-Gómez, Lloréns, Alcañiz *et al.* (2011), Bieryla and Dold (2013), and Gerling and Masuch (2011). Pyae, Luimula, and Smed (2016). They recommend motion-based controllers as being the most user-friendly for the elderly, compared with other types of game controllers (e.g. PlayStation's PlayMove and Controller). Although previous studies of the elderly showed the potential of different game controllers, there were limited studies to investigate their experiences with, and preferences for, different types of game controllers during gameplay (Pham & Theng, 2012).

2.3 **Research Gaps**

Although the existing literature has shown the potential of digital games for improving the elderly's physical well-being as well as their participation and motivation in physical exercises and rehabilitation, there are issues and challenges in digital games encountered by the elderly in terms of usability, user experience, and usefulness of such digital game-approach in physical exercise activity and rehabilitation. In this section, we state the research gaps highlighted by the literature review on usability issues and challenges by elderly players in playing digital games and multimodal input devices in gameplay.

2.3.1 Usability Issues with Digital Games for the Elderly

As digital games have been used for promoting the physical well-being of the elderly in terms of physical exercise activity and rehabilitation, it is important to understand the usability of existing games for this age group. To date, there are a number of scholarly investigations into the usability of digital games for the elderly. Both commercial and non-commercial games have been evaluated with elderly users to understand the issues they encountered whilst using the gameplay. The literature review provided useful recommendations and guidelines targeting areas for improvements to usability, game design, and interaction design for consideration by future designers and developers of digital games for the elderly (Gerling & Masuch, 2011). Gerling, Livingston, Nacke *et al.* (2012) evaluated full-body motion-control games for elderly participants and proposed usability guidelines for the design of full-body interaction in games. Planinc, Nake, and Kampel (2013) conducted a usability study of exergames to investigate their appropriateness for the elderly. Whitlock, McLaughlin, and Allaire (2011) evaluated digital games with elderly subjects and reported specifically on aspects of usability and made recommendations for future video game design to be sensitive to the causes of elderly users' negative experiences with games (e.g. to incorporate measures to counter adaptive difficulty). Marston (2013) proposes a series of design guidelines for designing and implementing digital game concepts for second and third-age adults based on results collected from an empirical study.

In the existing literature, researchers have proposed different usability guidelines for digital games for the elderly in general. For instance, Sáenz-de-Urturi, García Zapirain, and Méndez Zorrilla (2015) state that game tutorials that can mimic the gameplay can be useful for elderly players. According to Marin, Lawrence, Navarro *et al.* (2011), it's important to provide relevant game instructions in a particular game system so that elderly players can easily follow and play the game. Regarding the game content, Law and Sun (2012) suggest that familiar game themes should be used in a particular game system so that elderly players can easily understand and follow. Rodio and Bastien (2013) also suggest using encouraging and fun contents in the game while designing digital games for the elderly. The following Table 2.1 shows selected usability guidelines suggested by the existing literature by Veloso and Costa (2016).

Table 2.1 Game Usability Guidelines (Veloso & Costa, 2016)

Usability Guidelines	**Application**	**Authors**
Provide game tutorials that mimic the gameplay.	Game Help	Sáenz-de-Urturi, García Zapirain, and Méndez Zorrilla (2015) Marinelli and Rogers (2014)
Provide game instructions	Game Help	Marin, Lawrence, Navarro *et al.* (2011)
Use common and familiar themes that can be understood easily	Game Content	Law and Sun (2012)
Game objects follow the rules of daily life and foster the use of metaphors (e.g. avatars and scenes)	Game Content	Alfadhli and Alsumait (2015)
Encourage fun	Game Experience	Rodio and Bastien (2013) Sáenz-de-Urturi, García Zapirain, and Méndez Zorrilla (2015)
Provide positive game experience	Game Experience	Law and Sun (2012)
Design a realistic environment	Game Experience	Sáenz-de-Urturi, García Zapirain, and Méndez Zorrilla (2015)
Provide a meaningful game story that supports gameplay	Game Experience	Veloso and Costa (2016)
Provide achievements and trophies for players to acquire	Reward	Gavriushenko, Karilainen, and Kankaanranta (2015) Paavilainen (2010)
Give level difficulty options of the game	Level Design	Soomro, Wan Ahmad, and Sulaiman (2013)
Adjust the game challenges to the players' skills	Level Design	White, Mirza-babaei, McAllister *et al.* (2011)
Provide clear goals throughout play	Goal/Challenges	Alfadhli and Alsumait (2015) Marin, Lawrence, Navarro *et al.* (2011) Sáenz-de-Urturi, García Zapirain, and Méndez Zorrilla (2015)
Design game movements that are natural and clear and visible effects	Gameplay	Alfadhli and Alsumait (2015)
Provide immediate in-game feedback	Game Feedback	Rodio and Bastien (2013)

Provide information on players' game status	Game Feedback	Gavriushenko, Karilainen, and Kankaanranta (2015)
Present information/indicators relative to the players' performance in the game	Game Feedback	Gittens and Gloumeau (2015)
Motivational game design guidelines	Game Design	Pyae, Luimula, and Smed (2015)
Motion-based interaction	Game Interaction	Gerling, Livingston, Nacke *et al.* (2012)
Controller-based interaction	Game Interaction	Theng, Teo, and Truc (2010)

Despite having a noticeable number of studies in this research area, Floyd, David, and Ashot (2015) point out that the design of digital game-based exercises or exergaming is a difficult intertwined challenge to efficiently and effectively combine the technical aspect of digital games and the parameters of the physical effort the technology demands of the players. Hence, it is important to enhance the understanding of exergame designs and associated players' experiences especially for the elderly who have limited physical and functional ability due to the old age. Furthermore, the established researchers have encouraged upcoming design researchers to undertake a similar analysis to derive a more comprehensive picture of the nature of the interplay between the technical and human considerations needing to be fully taken into account when designing exergaming for the elderly. Palacio, Acosta, Cortez *et al.* (2017) also point out that it is important to explore and address a significant gap in terms of research on the usability perception of different digital games particularly for the elderly. Nawaz, Skjæret, Helbostad *et al.* (2016) state that it is unclear to which degree the usability of digital games for the elderly has been evaluated, and there is a need for a systematic approach in game development for the elderly particularly in physical game-based training. The need of more usability studies of digital games for the elderly to be undertaken is also highlighted by other researchers including Hongmei, Agama, and Prodanoff (2017), Garcia, Raffe, and Navarro (2018), Glännfjord, Hemmingsson, and Larsson Ranada (2017), and Ling, Ter Meer, Yumak *et al.* (2017).

2.3.2 User Experience Challenges for the Elderly

In the existing body of literature, digital games, there can be seen a noticeable number of studies that have investigated the user experiences of the elderly in playing

digital games particularly for physical exercise activity, rehabilitation, cognitive benefits, and social connection. According to Sayago, Rosales, Righi *et al.* (2016), the elderly's experiences of digital gameplay (i.e., motivations, practices, and preferences) have received considerable research attention over the past decade. The authors also state that much of this research is conducted using surveys, interviews, and observational studies with the involvement of active elderly players or the elderly who are interested in playing digital games. Furthermore, most of these research have been conducted with different elderly participants in different countries. For instance, Chesham, Wyss, Müri *et al.* (2017a) conducted a user experience study with 16 healthy older adults aged between 65 and 84 years in Switzerland to investigate their acceptance and preference of casual video games (CVGs), and their findings show that these CVGs are suitable and enjoyable for older adults. Vaziri, Aal, Ogonowski *et al.* (2016) also conducted an international, multicentre study with a total of 153 community-dwelling older adults from Germany, Spain and Australia to study the user experience, usability, and user acceptance of iStoppFalls fall prevention game-based system for older adults, and their findings show that the system has good usability, user experience, and user acceptance. In the context of Asia, Chia, Cheng, Hnin *et al.* (2018) designed and implemented a user-friendly interface for a Virtual Integrated Therapy for Active Living (VITAL) - Health Box for the elderly population in Singapore and a usability evaluation was conducted with 10 Singaporean elderly participants. Their study reports the interface guidelines for better user experiences for the elderly. Although we can see a noticeable amount of work for game user experiences for the elderly in different countries, there is a limited number of studies regarding the elderly's user experiences in digital games in the context of Finland and with elderly Finns. Furthermore, there is also a limited study of elderly Finns' attitudes towards digital games and motivation to do game-based physical activities including regular exercises and rehabilitation training. Thus, the literature clearly shows that more studies needed to undertake to better understand whether elderly Finns accept digital games as an intervention for their physical exercise as well as rehabilitation. More importantly, it is necessary to conduct more usability studies of digital games for elderly Finns so that we can design user-friendly and usable game systems for elderly Finns to promote their physical health.

2.3.3 Challenges of Commercial Games

Despite considerable research demonstrating their potential, there are significant problems for the elderly when using digital games, and gaps in the research

into this. Gerling and Masuch (2011) point out that not all commercial games are accessible to the elderly. They conducted an exemplary focus group analysis of Wii Sports and Wii Fit games with frail elderly players, and a variety of usability issues were observed during the gameplay sessions. These issues included low-level controller malfunctions, inadequate player feedback, and overly demanding in-game challenges. They also suggest that it is necessary to design games specifically for elderly users in order to provide a positive gaming experience for that age group. Marinelli and Rogers (2014) also point out that the design and gameplay of most exergames available on the market are not elderly-friendly. They evaluated two exergames for Microsoft Xbox 360 with elderly players, and found significant usability issues, in particular poor visibility of system status updates, inadequate user control and freedom, excessive game speed, and too high a level of difficulty in both the technical and human operational competencies required, such that these aspects of games design would act as a deterrent to continued use by elderly players.

Harrington, Hartley, Mitzner *et al.* (2015) highlight that most of the game systems on the market are not designed to accommodate the physical and cognitive limitations of the elderly, in particular, visual impairments and reduced sensorimotor skills. According to Webster and Celik (2014), Kinect-based exercise games have limitations such as game designs for specific players, game customization, lack of effective feedback, and lack of long-term study. Marin, Lawrence, Navarro *et al.* (2011) state that the use of digital games by the elderly requires an in-depth inspection of the game's design and the technical and physical competencies needed by the elderly user to ensure they can reap optimum benefits for their healthcare outcomes. The authors point out that it is important for designers to understand the capabilities, limitations, and interests of the elderly to create successful game stories and mechanics. According to TNO and VitaValley (2017), the current market for exergames for the elderly is still in its infancy, and the existing range of games is too limited. In addition, the authors point out that there is a need for new types of games catering to the specific requirements and different characteristics of elderly users.

Although the existing literature shows that exergames have shown the potential to make physical activity more appealing and engaging; it should be noted there is a limited number of studies that investigate the limitations of existing commercial digital games for the elderly. For instance, researchers have reported the potential of Nintendo Wii and Microsoft Xbox games for the elderly; however, there is limited research in the next generation of commercial games for the elderly beyond Wii or Xbox technologies. Most of these existing commercial games make demands on working memory and a

great deal of learning and information processing, which may be difficult for some elderly players. Thus, there is a need to better account for age-related changes that may affect game system usability for elderly users. Furthermore, it is important to undertake further research to reduce the barriers for the elderly to use digital games as an alternative way of doing physical exercise. According to Harrington, Hartley, Mitzner *et al.* (2015), it is still unclear whether the existing digital game systems, which in the short term allows the elderly users to be challenged by the game system, will also in the long term motivates them to continue using these game systems over an extended period. It should also be noted that the existing literature is also limited in elderly Finns' user experiences in playing commercial games for their physical exercise activity.

2.3.4 Interactive Multimodal Input Devices for the Elderly

There are a number of interactive multimodal input devices available in the market that can be used for playing digital games including the Microsoft Kinect sensor, Nintendo Wii Remote, Wii Fit, Dance Dance Revolution Dance Pad, touch-based interaction, and a traditional game controller with buttons. Among them, Microsoft Kinect and Wii devices (e.g. Wii Remote and Fit balance board) have been used by many researchers, and have shown potential for easy use by the elderly. For instance, Pham and Theng (2012) conducted an experimental study of elders' preferences in using different game controllers, and their findings show that Microsoft Kinect was the most preferred controller amongst this age group Gerling, Livingston, Nacke *et al.* (2012) suggest that full-body motion-based games can accommodate a variety of user abilities, and can have a positive effect on the mood and emotional well-being of elderly users. Although there are a number of studies concerning the usability and usefulness of these interactive multimodal input devices for other user groups, such as young adults, little is known about the older user group (Pham & Theng, 2012). Thus, further investigation should be conducted with older users to assess the usability and usefulness of these multimodal devices in order to successfully improve this cohort's positive experience and enjoyment whilst playing digital games.

2.4 Focus of the Study and Justifications for the Research Questions

In this study, we focused on using digital games for promoting elderly Finns' physical well-being in terms of their engagement in regular physical exercise activity as

well as their rehabilitative training. As stated in Chapter 1, the main objective of the GSH project is to provide a digital game-based platform for elderly Finns to do their physical exercises. Furthermore, we aimed to provide a digital game-based physical training for elderly Finns' rehabilitation. Thus, in GSH, we aimed at creating a digital game-based physical exercise activity for elderly Finns in which they can do both physical exercises and rehabilitation. The literature review in this study also shows that digital games have shown great potential for the elderly's physical well-being in terms of physical exercise and rehabilitation. However, the existing literature also shows that there are research gaps still needed to address to provide user-friendly digital games for the elderly. Furthermore, we found that there is limited research in this area, particularly for elderly Finns. To address the research gaps mentioned in the previous section, the following four research questions were formulated for this study, and in this section, we discuss why each research question is important to investigate.

"***RQ1****: What are the user experiences of elderly Finns in playing digital game-based physical exercise activity?"* Our review of the literature indicated that although digital games have shown their potential to promote physical well-being for the elderly user, further research is required to contribute to the advancement of the field, which will lead to better game designs and improvements in players' experiences. Furthermore, to the best of our knowledge, there is limited research in this area of digital game-based exercises for elderly Finns, especially their attitudes towards digital games, in-game and post-game user experiences, and motivation to play digital game-based exercises. Thus, it is important to investigate elderly Finns' user experiences whilst playing digital games, so that healthcare practitioners in Finland can take into account how best to use digital games to promote physical activities by the elderly in aged-care settings, particularly service homes and home-based services. Furthermore, this study can help game designers and developers not only in Finland but also in other countries gain insights into designing and developing user-friendly digital game-based exercises for the elderly.

"***RQ2:*** *What are elderly Finns' perceptions of playing digital games as an alternative way for undertaking a physical exercise activity?*" The literature highlights that not all digital games are user-friendly for the elderly due to the elderly users' age-related physical and cognitive limitations. Although previous studies report digital games' potential to increase physical activity by the elderly, there is no or limited prior study reporting the use of digital games by elderly Finns as an alternative way of exercising. Furthermore, to the best of our knowledge, neither is there any prior research into elderly Finns' perception of the benefits of digital game-based physical

exercise activity, nor any study into their intention to use digital games as an alternative mode of engaging in physical exercise. Hence, it is important for us to bridge this gap to better understand the potential of digital games for the elderly in the context of physical exercises. In this way, policymakers and health practitioners, especially in Finland, can gain insights from this study into how best to incorporate digital games into their programs to promote the physical health and well-being of the elderly in either service homes or home-based settings. It can also help digital game companies, especially in Finland, gain insights into producing usable and feasible digital games for the elderly in engaging their physical exercises.

"***RQ3****: What are the usability challenges encountered by elderly Finns whilst engaged in a digital game-based physical exercise activity?*" The existing literature states that although there are a significant number of prior studies of the elderly and their perception of game usability, it is important to further investigate the usability of digital games for increasing rates of commitment to ongoing physical exercise specifically by elderly Finns. Thus, this study explores and recommends usability guidelines for digital games especially for elderly Finns engaged in physical exercises. These guidelines can provide useful insights and parameters for game designers and developers to take into account when designing and developing elderly-friendly digital games. The more we understand the usability of digital games for elderly Finns, the better we implement user-friendly and effective digital game-based exercises for them. Also, the findings can provide useful and insightful advice not only for the Finnish game companies but also for those researchers in Finland and overseas who are working on similar research.

"***RQ4****: What are the differences in user experiences, usefulness, and usability of digital game-based physical exercise activity between the Finnish and non-Finnish elderly people?*" One of the aims of the GSH project is to customize for different countries the digital game-based exercises produced by the Turku Game Lab so that we can help the ageing society not only in Finland but also across the world. Although digital games implemented for the GSH project are primarily targeted at promoting elderly Finns' engagement with physical activities, our goal was to examine whether digital game-based exercises designed for elderly Finns can also be user-friendly to non-Finns. Therefore, it is important to investigate the comparative differences in Finnish and non-Finnish elderly users' experiences, the usefulness, and usability of the games. Understanding the differences between two elderly groups will provide useful insights for the GSH project's worldwide promotion of improved physical health for the elderly, in the context of locating the Finnish games into an international marketplace to promote the elderly's physical health worldwide.

2.5 Summary

In this chapter, we reviewed the existing literature on the potential benefits of digital games for the elderly's physical well-being in terms of physical exercise activity and rehabilitation. We also assessed different digital game platforms, which have shown potential to improve rates of engagement with, and successful maintenance of, an ongoing program of both supervised and self-regulated physical exercise and rehabilitation across a range of healthcare settings for elders in both independent living and serviced aged care domiciles. Furthermore, we reviewed the existing commercial games, which have been used by healthcare practitioners, researchers, and designers to improve the elderly's physical health. We also reviewed the existing literature to understand the research gaps that require further study and detailed the parameters of our new investigation. Lastly, we justified the selection of the research questions formulated for our study and detailed the reasons they would and indeed did, deliver worthwhile investigative outcomes.

Chapter 3
Methodology

This chapter outlines the research philosophy and methods applied in this study, and the justification for using the mixed methods approach, which includes both qualitative and quantitative research methods. The data collection methods that we used in this study (questionnaire, participants observation, and interview) are also described and discussed. Lastly, the detailed research design and activities are outlined in this chapter.

3.1 Research Philosophy and Worldview

Research philosophy is defined as "*examining the nature of knowledge itself, how it comes into being and is transmitted through language*" (Patton, 2002, p.92). Research philosophy is also defined as a belief that shows the way in which data about a phenomenon should be gathered, analyzed, and used (Davison, 2016). According to Crossan (2003), understanding research philosophy can help a researcher refine, specify, and clarify the research methods that will be used in a particular study. "*Philosophy*" and "*Worldview*" are closely associated, and the latter is concerned with the way in which things are viewed in the world (Ihuah & Eaton, 2013). Creswell (2009) suggests that there are four different philosophical worldviews: post-positivism, constructivism, and advocacy and participatory, and pragmatism.

According to Creswell (2009, p.7), post-positivism is defined as "*the problems studied by post-positivists reflect the need to identify and assess the causes that influence outcomes, such as found in experiments*". Frank (2008, p.7) defines social constructivism as "*learners learn concepts or construct meaning about ideas through their interaction with others, with their world, and through interpretations of that world by actively constructing meaning".* Creswell and Clark (2014, p.97) define that "*the advocacy and participatory worldview provides an umbrella paradigm to the project*". This includes political action, empowerment, collaborative, and change-oriented research perspectives.

For this study, the pragmatic worldview is applied. According to Creswell (2009), pragmatism is defined as "*a worldview that arises out of actions, situations, and consequences rather than antecedent conditions*". In the pragmatic approach, researchers basically focus on the research problem and use all possible methods to investigate a particular problem (Rossman & Wilson, 1985). The pragmatic approach focuses attention on the research problem in social science research; it uses pluralistic methods

to derive knowledge about the problem (Morgan, 2007). According to Patton (2002), pragmatic worldview includes the researcher's perspective on what works best in choosing a particular research design. Creswell and Clark (2014) also state that a pragmatist's approach links the choice of approach directly to the purpose for and the nature of the research questions developed. The reason why this research worldview was selected for this PhD project is that in this philosophical worldview, researchers can use a blended approach in which both qualitative and quantitative research methods are mixed. In this study, we also aimed to apply both qualitative and quantitative methods to investigate elderly Finns' user experiences while playing digital game-based physical exercises. We concluded that this philosophical worldview was suitable for the purposes and applied nature of our investigation as the basis for a mixed methods approach. In the following sections, we will elaborate on the research methodology and the justification of the use of mixed methods approach in this study.

3.2 **Research Methodology**

A research methodology is derived from the stance of a philosophical worldview which in turn informs the style of research (Sapsford & Jupp, 2006). Clough and Nutbrown (2002) state that research methodology refers to the reasons for using a particular research recipe, while methods are the ingredients of it. According to Kothari (2004), research methodology is a way to solve the research problem systematically. It can also be understood as a science of studying how research is done in a scientific way (Kothari, 2004). Research methodology can be defined as the study of methods in which new knowledge is gained (Rajasekar, Philominathan, & Chinnathambi, 2013). According to Creswell (2009), there are three different research methods used by researchers: qualitative, quantitative, and mixed methods approaches. This is supported by William (2007, p. 65) stating that "*the researcher anticipates the type of data needed to respond to the research question. Based on this, the researcher selects one of these three methods to conduct a particular research*".

Bricki and Green (2007) define the qualitative method as an approach that aims to understand some aspects of social life, and this method generates words rather than numbers for the analysis of data. Quantitative methods test objective theories by investigating the relationship between variables, and can be measured by instruments and analyzed using statistical methods (Creswell, 2009). This method is basically associated with mathematics, statistics, and numbers. The mixed methods approach involves the use of both qualitative and quantitative techniques in different stages of the

research (Terrell, 2011). The following Figure 3.1 shows the research design of the study.

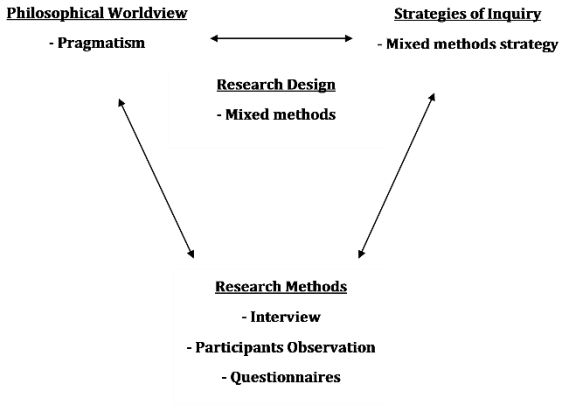

Figure 3.1 Research Design (Creswell, 2009)

3.2.1 The Rationale for Using Mixed Methods in this Study

In this study, we used the mixed methods approach. According to Malina, Norreklit, and Selto (2010), the mixed methods approach employs both qualitative and quantitative approaches iteratively or simultaneously. It creates a research outcome stronger than using individual methods, either qualitative or quantitative. The combination of quantitative and qualitative methods can help researchers to explore more complex aspects and relations within the human and social world (Malina, Norreklit, & Selto, 2010). It can also provide the flexibility of choices, which allows both sequential and concurrent strategies as well as both qualitative and quantitative methods (Terrell, 2011). The mixed methods approach provides a more comprehensive and complete explanation of any phenomenon being researched, by using both qualitative and quantitative approaches (Denscombe, 2003). It also provides clearer links between two different methods: qualitative and quantitative, and the different kinds of data being investigated (Denscombe, 2003). In this study, we will use a non-experimental study (utilising questionnaires) as a quantitative approach. We will also use interview and participant observation as qualitative methods. For the mixed methods approach, we will use a convergent parallel strategy. Table 3.1 shows the strategies of inquiry to be used in this study.

Table 3.1 Strategies of Inquiry (Creswell, 2009)

Quantitative	Qualitative	Mixed Methods
Non-experimental design such as questionnaires	Usability testing An exploratory study such as interview and observation	Convergent parallel mixed methods strategy

In this study, we used the convergent parallel mixed methods strategy to simultaneously collect, analyze, and interpret both qualitative and quantitative data (Caruth, 2013). According to Creswell and Plano-Clark (2017, p. 67), the convergent parallel mixed methods strategy is defined as "*the convergent design is a mixed methods design in which the researcher collects and analyses two separate databases—quantitative and qualitative—and then merges the two databases for the purpose of comparing or combining the results*". The authors also state that the convergent parallel mixed methods occurs when the researcher intends to bring together the results of both quantitative and the qualitative data analysis so they can be compared or combined to have more complete understanding of a problem and to validate one set of findings with the other (Creswell & Plano-Clark, 2017, p. 65). Bazeley (2019, p. 60) also describes that in the convergent parallel design, both qualitative and quantitative data strands are equal given status and are collected concurrently, leading to joint interpretation. The convergent parallel mixed methods design is suitable for our research because the research philosophical world view '*Pragmatism*' in this study is well suited for guiding the work of combining the two approaches into a larger understanding of the research problem and scope (Creswell & Plano-Clark, 2017). Also, in convergent parallel mixed methods strategy, both quantitative and qualitative methods are equally important for addressing the study's research questions. Furthermore, it allows us to collect both quantitative and qualitative data about the topic of research interest concurrently, but separately and independently while one method does not depend and influence the other. In this way, we could obtain both quantitative and qualitative results to be merged and compared in the later staged followed by an interpretation. Figure 3.2 explains the convergent parallel mixed methods strategy used for the study.

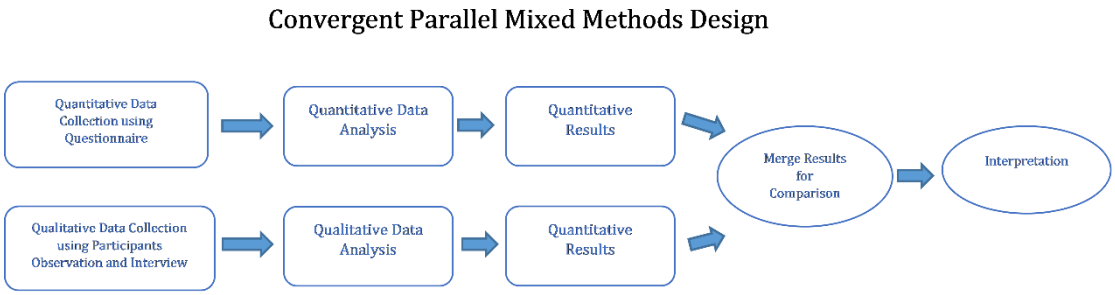

Figure 3.2 Convergent Parallel Mixed Methods Strategy (Creswell, 2013)

In this study, we aimed at addressing the research question #RQ1 "*What are the user experiences of elderly Finns in playing digital game-based physical exercise activity?*". To address this research question, the quantitative data from the questionnaires were analyzed to understand the elderly participants' user experiences in terms of in-game, post-game, attitudes, and motivation in the gameplay. The findings from the quantitative data were also supported by the findings from the qualitative method in which we conducted participants observation and user interviews. The same research method and approach were used in addressing the research question #RQ2 "*What are elderly Finns' perceptions of playing digital games as an alternative way for undertaking a physical exercise activity?*". Also, to address research question #RQ3 "*What are the usability challenges encountered by elderly Finns whilst engaged in a digital game-based physical exercise activity?*", using the quantitative research method, we analysed the results from questionnaires in this study, which helped us understand the usability of digital game-based exercise — *Skiing Game*. The quantitative findings from the usability questionnaire were compared and supported by the qualitative findings from the interview. Furthermore, through the qualitative method — participants' observation, we identified usability issues encountered by the elderly participants and these provided helpful insights, which allowed us to better frame recommendations and usability guidelines for future digital game design and development tailored for elderly users. Lastly, we interpreted and discussed both quantitative and qualitative findings simultaneously to answer the research questions #RQ4 "What are the differences in user experiences, usefulness, and usability of digital game-based physical exercise activity between the Finnish and non-Finnish elderly people?".

3.3 Data Collection and Analysis Methods

To collect qualitative data from the participants, the interview was used as a qualitative research method in this study to investigate elderly participant's feedback, response, and their experiences in the gameplay. Creswell (2009) states that in qualitative interviews, a researcher can conduct a face-to-face interview with participants, or by telephone or email. Interviews involve open-ended questions, which are intended to elicit participants' views and opinions. According to McNamara (1999), interviewing is useful for understanding the story behind a user's experiences. Furthermore, it can seek in-depth information about the target research topic from the participants. In this study, we used open-ended interview questions in the usability studies of *Skiing Game* with both elderly Finns and Japanese elderly people to understand the usability, user experience, and usefulness of digital game-based exercise for them. We also applied participant-observation as a qualitative method in this study to observe the elderly users' interaction with the game system. Marshall and Rossman (1989) state that participant observation is the systematic description of events, behaviours, and artefacts within the social environment and setting chosen for a research study. It includes active looking, improving memory, informal interview, and writing field notes (DeWalkt & DeWalt, 1998). According to Coffey (2006, pp. 215-216), participants observation is also defined as "*A qualitative method of social investigation, whereby the researcher participates in the everyday life of a social setting, and records their experiences and observations*". Specifically, in the usability studies of *Skiing Game*, we applied the note-taking method to understand the elderly participants' interaction with the game system, gameplay experiences, and usability challenges encountered during the gameplay.

In the usability study of *Skiing Game* with elderly Finns and Japanese elderly people, we used questionnaires as a quantitative method to collect data from the elderly participants in this study. For instance, we used the System Usability Scale by Brooke (2013), Game Experience Questionnaire by IJsselsteijn, Kort, and Poels (2017), and User's Attitude by Terry, Biddle, Chatzisarantis *et al.* (1997) questionnaires to collect such data from the elderly participants as the usability of the game, their user experiences, and attitudes towards playing digital games. We used a 5-point Likert scale for all questionnaires in this study. According to Rogers, Sharp, and Preece (2012), questionnaire is a well-established technique used in quantitative research, to collect demographic data and the opinions of participants. Kendall (2008) states that questionnaires and interview approaches are used together in mixed methods research

because questionnaires can basically provide the evidence of patterns of data among large populations while qualitative interviews can gather more in-depth data from participants in terms of their attitudes, thoughts, and actions.

System Usability Scale (SUS)

In this study, to investigate the elderly participants' feedback towards the usability of the *Skiing Game*, we used the System Usability Scale (SUS), which is simple and easy-to-understand. According to Brooke (2013), SUS includes a 10-item questionnaire, which includes the subjective assessments of the usability of a particular system or device. Generally, SUS is based on the 5-point Likert scale from *Strongly disagree* (1) to *Strongly agree* (5). By using SUS, we can evaluate a variety of products and services, including software and hardware systems, mobile devices, applications, and websites. Furthermore, the SUS scale can be used for small sample size, and it is easy to apply to participants. Sauro (2011) states that while SUS is intended to measure perceived ease-of-use of a system, it can also provide not only the usability but also learnability dimensions of a particular software or hardware system. Brooke (2013) advocates that SUS is technology-neutral, and it has been continuously used as technology develops over the years without reinvention of questionnaires. Bangor, Kortum, and Miller (2009) also mention that SUS is an effective tool for measuring the usability of a system or product, and it provides a score from 0 to 100, which is easy-to-understand for participants particularly elderly people. In this study, we modified the SUS questionnaires to be suitable for the aims of the study. As an example, the original version of SUS refers to a particular system; whereas, in our study, it refers to a game system and its usability. By using SUS, we aimed at answering the research questions #RQ3 and #RQ4, and also supporting #RQ1. Table 3.2 shows the revised version of the SUS questionnaires that are used in our usability testing of the *Skiing Game*.

Table 3.2 System Usability Scales

Item	**SUS Question**
1	I think that I would like to play this game frequently.
2	I found this game unnecessarily complex.
3	I thought this game was easy to play.
4	I think that I would need the support of a technical person to be able to play this game.
5	I found the various functions in this game were well integrated.
6	I thought there was too much inconsistency in this game.
7	I would imagine that most people would learn to play this game very quickly.
8	I found this game very cumbersome to play.

Item	SUS Question
9	I felt very confident in playing this game.
10	I needed to learn a lot of things before I could get going with this game.

Game Experience Questionnaires (GEQ)

In this study, we used GEQ to understand the elderly participants' experiences during and after playing the *Skiing Game*. To assess the elderly participants' in-game and post-game experiences, we used two GEQ modules (IJsselsteijn, de Kort, & Poels, 2015). In GEQ, the in-game module is basically used to assess a player's game experience during a game-play session. This in-game module consists of seven components including sensory and imaginative immersion, flow, competence, positive affect, negative affect, tension, and challenge (de Kort, IJsselsteijn, & Poels, 2007). According to Norman (2013), GEQ is a reasonable and applicable questionnaire to explore a player's experiences with a game and it has been widely and successfully used in many studies internationally. In this study, we used GEQ to answer the research questions #RQ1 and #RQ4. The GEQ in-game components and response options from the questionnaires are mentioned in Table 3.3.

Table 3.3 Game Experience Questionnaire (GEQ) In-game Module

In-game GEQ components	Response option
Sensory and Imaginative Immersion	I was interested in the game's story. I found it impressive.
Flow	I forgot everything around me. I felt completely absorbed.
Competence	I felt successful. I felt skillful.
Positive affect	I felt content. I felt good.
Negative affect	I felt bored. I found it tiresome.
Tension	I felt frustrated. I feel irritable.
Challenge	I felt challenged. I had to put a lot of effort into it.

In this study, we used the GEQ post-game questionnaire, which is used to assess how the elderly participants felt after they have played the *Skiing Game* (IJsselsteijn, Kort, & Poels, 2017). Basically, it has four components including positive experience, negative experience, tiredness, and returning to reality. In GEQ, the positive experience component represents player's positive experiences after playing the game such as

satisfaction, victory, and power (e.g. I felt satisfied). Whereas, negative experience is about a player's bad experiences after he or she has played the game (e.g. I felt bad). The component tiredness refers to a player's exhaustion in the gameplay (e.g. I felt exhausted). Lastly, returning to reality is about a player's disorientation after he or she has played the game (e.g. I found it hard to get back to reality). The GEQ post-game was used to answer the research questions #RQ1 and #RQ4. The GEQ postgame components and response options from the questionnaires are described in Table 3.4.

Table 3.4 Game Experience Questionnaire (GEQ) Post-game Module

Post-game GEQ components	**Response option**
Positive Experience	I felt revived. It felt like a victory. I felt energized. I felt satisfied. I felt powerful. I felt proud.
Negative Experience	I felt bad. I felt guilty. I found it a waste of time. I felt that I could have done more useful things. I felt regret. I felt ashamed.
Tiredness	I felt exhausted. I felt weary.
Returning to Reality	I found it hard to get back to reality. I felt disoriented. I had a sense that I had returned from a journey

Post-Gameplay Interview Questions

In this study, we created the post-gameplay interview questions based on the Senior Technology Acceptance & Adoption Model (STAM). The questions include the following four items that investigate the elderly participants' perceptions of digital games for physical exercise activities. First, we used the perceived usefulness question to understand the effectiveness and usefulness of digital games. Second, we used perceived ease-of-use to examine if playing the *Skiing Game* was easy for the elderly participants. Third, gerontechnology self-efficacy was used to understand if the elderly participants could easily play after receiving the game instructions and to determine if the game instructions were adequate. Lastly, gerontechnology anxiety was used to

examine if the elderly participants were afraid of making mistakes while playing the game. The post-game interview questions were used to answer the research questions #RQ2 and #RQ4. Table 3.5 shows the post-gameplay interview questions.

Table 3.5 Post-game Interview Questions

Post-game questions	
Perceived Usefulness	Could playing digital games be an effective and effortless way of exercising?
Perceived Ease-of-Use	Was playing the game easy?
Gerontechnology Self-Efficacy	Were you able to play the game after receiving instructions? Would the user instructions have been adequate?
Gerontechnology Anxiety	Were you afraid of making mistakes when playing the game?

Data Analysis

In this study, we used both quantitative and qualitative methods to analyze the data collected from both the Finnish and Japanese usability studies of the *Skiing Game*. For the quantitative method, we used the SPSS software to conduct the statistical analysis of data collected from the questionnaires in the usability studies. For the qualitative analysis, we used Nvivo software to conduct the thematic analysis of data collected from the interviews and note taking in the usability studies.

3.4 Study Design

In this research project, there are four major stages: requirements gathering, analysis and design, prototyping, and evaluation. For requirements gathering, a number of pre-studies were undertaken to firstly understand what requirements need to be met in order to interest particularly for elderly Finns in engaging with and maintaining physical exercises. Secondly, to ensure participants fully understood the potential health benefits of using digital games for promoting their physical activity and rehabilitation through exercise activities. This includes a literature review focusing on digital games for the elderly and their importance to a successful program of physical exercise and rehabilitation. For the literature review, we conducted a systematic literature review that includes commercial games for the elderly, motivational game design, and related studies of digital games for the elderly's physical well-being. In pre-studies, we also

conducted a number of interviews and observations at the elderly service homes in Finland to understand the elderly's needs in doing physical exercises and rehabilitation. In addition, we conducted mapping and evaluation of the existing game systems such as Nintendo Wii and PlayStation games done by the health informatics students and researchers from the Turku University of Applied Sciences in Finland. Lastly, in the pre-studies, we conducted user testing of commercial games and in-house games with the elderly participants using games such as Xbox Kinect-based games, PlayStation games, and Puuha's SportWall in-house games. We also evaluated the usability and the elderly's user experiences in using multimodal input devices in gameplay, which included Xbox Kinect motion controller, PlayStation's PlayMove controller, and Xbox traditional game controller. In the user testing of digital games, we used both quantitative and qualitative methods simultaneously to collect data from the elderly including questionnaires, interviews, observation, and note-taking.

For analysis and design, we analyzed, compared, and interpreted both data collected from the pre-studies to ideate interactive digital games for the elderly. We used both qualitative and quantitative methods in the analysis and design phase including thematic analysis and statistical analysis. In this analysis stage, we consulted with healthcare professionals such as nurses and therapists to make sure that the findings from the analysis were relevant to the elderly's needs and wants. After the analysis and design phase, then, through multiple consultations with health and design experts, we then designed a digital game-based physical exercise system for the elderly, followed by the implementation of a digital game system called the *Skiing Game* tailored especially for elderly Finns' exercise activities. In the design and development phase, we used the game development tool called Unity3D followed by functional testing of the prototype. From the requirements gathering to prototyping stages, they were iterative in the design process.

For the evaluation stage, we aimed to investigate the usability, user experience, and usefulness of digital game-based exercises for elderly Finns. In this usability testing, we applied the convergent parallel mixed methods design to obtain different but complementary data on the same research questions so that we can better understand the research problem stated in this study. We simultaneously used both qualitative and quantitative methods to collect, analyze, and interpret data from the Finnish elderly participants. We used questionnaires for collecting quantitative data while participants observation and interviews were used for collecting qualitative data from the participants. In the pre-gameplay, we collected both qualitative and quantitative data from the participants by using questionnaires and open-ended interviews to understand

the elderly participants' prior experiences in gameplay, their perceptions of digital games, their physical exercise activities, and to collect their demographics. During the gameplay, we only used the qualitative method by observing the participants' interaction with the game system and usability issues they encountered during the gameplay. In the post-gameplay, we used both qualitative and quantitative methods by using questionnaires to investigate the participants' user experiences, usability, and usefulness of digital game-based exercise for them. We used SUS and GEQ questionnaires in the post-study. In addition, we used open-ended interview questions to collect qualitative data from the participants to understand the usability, user experiences, and usefulness of digital game-based exercises for elderly participants. We also used semi-structure interview questions – adapted from STAM to understand the elderly participants' perceptions of digital games as an alternative means of playing exercises. After conducting both usability studies of *Skiing Game*, we analyzed, interpreted, and compared quantitative results with qualitative findings for a complete understanding of the research questions. Table 3.6 lists the step-by-step usability study design and procedures.

Table 3.6 Step-by-Step Usability Study Design and Procedures

Usability Study Stage	**Tasks**	**Duration**
Pre-study	Pre-study questionnaire and interview about participant's prior experiences and demographic	20 minutes
	Pre-gameplay tutorial	20 minutes
Break		15 minutes
In-game study	Gameplay by participants (observed by two researchers)	30 minutes
Break		15 minutes
Post-game study	Questionnaires using SUS and GEQ	20 minutes
	Post-gameplay open-ended interview session	20 minutes

In this study, we also conducted a cross-country usability testing with the non-Finnish elderly outside of Finland to investigate whether there are any differences in user experiences between elderly Finns and elderly non-Finns whilst playing digital

game-based exercises. The main objective of the cross-country usability study of the *Skiing Game* was to examine if digital games designed for elderly Finns are accepted by non-Finnish elderly people outside of Finland. In this Japanese usability testing of the *Skiing Game*, we also applied the same research design, methodology, data collection techniques, and analysis that we used in the Finnish usability study of the *Skiing Game*. After conducting both usability studies, we combined, consolidated, and analyzed data from both studies to examine whether there were differences between two elderly groups: elderly Finns and the Japanese elderly people. Furthermore, we applied both qualitative and quantitative methods to analyze the combined data and made usability recommendations for digital games for the elderly's physical exercise activity that can be applied for not only elderly Finns but also the elderly outside of Finland.

In GSH, the author involved in requirements gathering or pre-studies including literature review, the usability testing of commercial games, interviews, and observations at elderly homes in Finland. Also, the author participated in analysis and design that includes mapping existing games, testing of different game consoles and devices, brainstorming, and designing game prototypes. In the functional prototyping of the game system, the author involved in the project as a research consultant, and interaction designer. In the Finnish usability testing of the *Skiing Game*, the author participated as the main researcher and conducted study preparation, data collection, data analysis, and manuscript preparation. In the Japanese usability study, the author participated as a research consultant, data analysis, and manuscript preparation. The following Table 3.7 lists the different stages of the study.

Table 3.7 Step-by-Step Research Design

Stage	Research Activities	Description	Methods
Requirements Gathering	Pre-study 1	Mapping existing games (e.g. Nintendo Wii, Microsoft Xbox games, and PlayStation games) by health informatics researchers and students from TUAS, Finland Observation and interviews at the selected elderly service homes in Finland	Qualitative • Observation • Interview Quantitative • Questionnaire
	Pre-study 2	Literature review on the motivational game design for the elderly	Qualitative and Quantitative • Systematic Review
	Pre-study 3	A review of commercial games available in the market and usability testing of existing games, including Microsoft Xbox Kinect games, PlayStation games, and Puuha's SportWall game (with 30 participants in Finland)	Qualitative • Observation • Interview • Systematic Review Quantitative • Questionnaire • Systematic Review
	Pre-study 4	Usability testing of interactive multimodal input devices for the elderly in gameplay (with 12 participants in Finland)	Qualitative • Observation • Interview Quantitative • Questionnaire
Analysis and Design	Analysis of data	Analyze the data collected from the pre-studies (collaborated with the team members from the Turku Game Lab and healthcare professionals from elderly homes in Finland)	Qualitative • Observation • Interview Quantitative • Questionnaire
	Design and early prototyping	Design early game prototypes based on the findings from the analysis (collaborated with the	Paper-based Prototyping and Functional Prototyping

		team members from the Turku Game Lab and healthcare professionals from Finland)	
Prototyping	Functional prototyping	Implementation of digital game-based physical exercise game called the *Skiing Game* for the elderly (developed by the team members of the Turku Game Lab)	Game Design and Development using Unity3D with C# programming Game Arts Creation
Evaluation	Finnish usability testing	Evaluate the game system with elderly Finnish participants in Finland (with 21 elderly Finns as participants in Turku, Finland)	Qualitative • Observation • Interview Quantitative • Questionnaire
	Japanese usability testing	Evaluate the game system with elderly Japanese participants in Japan (with 24 elderly Japanese as participants in Sendai, Japan)	Qualitative • Observation • Interview Quantitative • Questionnaire
	Comparative study	Analyzed and compared data collected from both Finnish and Japanese usability studies of the *Skiing Game*	Quantitative and Qualitative analysis using SPSS and Nvivo software

3.5 Summary

In this chapter, we discussed the research philosophy *'Pragmatic Worldview'* used in this study, and the mixed methods research approach, using both qualitative and quantitative research methods. Then, we discussed the data collection methods used in this study as well as the data analysis methods applied in this study. Lastly, we described the detailed research design and activities.

Chapter 4
Requirements Gathering, Analysis, Design, and Prototyping

This chapter outlines the requirements gathering, analysis and design, and prototyping stages of the study. For requirements gathering, we conducted four pre-studies – mapping existing digital games for the elderly, the literature review, review of commercial games, and the pilot usability testing of commercial games and in-house games developed by the Turku Game Lab and Puuha Group, Finland. Based on the findings from the pre-studies, we analyzed and designed a digital game-based physical exercise for the elderly called the *Skiing Game*. Then, we implemented the functional prototype of the *Skiing Game*. Reference is made to the relevant publications where full details of the studies are elaborated and reported.

4.1 Pre-studies

In this project, we conducted a total of four pre-studies to elicit users' requirements, including the elderly's reported problems and perceived needs for initiating and maintaining participation in physical exercises and rehabilitation. The pre-studies include mapping existing commercial games for the elderly's physical exercise activities and rehabilitation, observation, and interview at elderly service homes in Finland. We also conducted a literature review with a focus on the potential of digital games for the elderly and motivational factors in doing rehabilitation training. Then, we evaluated the existing commercial games, interactive multimodal input devices for gameplay, and in-house games by the Turku Game Lab and Puuha Group, Finland to assess the usability for the elderly as well as their user experiences.

4.1.1 Pre-Study 1: Mapping Existing Games and Interviews

The pre-study #1 focused on mapping existing commercial digital games for the elderly, as well as conducting an interview and observational studies at elderly service homes in Finland. The main objectives of pre-study #1 are : (1) to investigate whether existing commercial digital games are suitable, usable, and useful for the elderly's physical exercise activities, (2) to understand the elderly's perspectives and attitudes towards digital games, and (3) to observe their physical, social, recreational, and rehabilitation activities at elderly homes. In the pre-study #1, we selected different commercially available games in the market that will be used for our future usability

testing with the elderly participants in Finland. A team of 12 health informatics researchers and students involved in the study to test different console games and identified the games' actions that can be potentially used to improve elderly people's physical and rehabilitation activities. In the selection, we focused on game usability, game design, and gameplay that are senior-friendly and promising to promote the elderly's physical and rehabilitation activities. Furthermore, the potential usability problems of the commercial games for elderly users were identified such as user interface, feedback, rewards, language options, tutorials, personalization, and calibration of the game. Furthermore, in this pre-study, we observed the elderly's physical activities at the elderly homes in Finland to understand their participation in regular physical exercises and rehabilitation. We also interviewed the elderly, nurses, and therapists to understand their respective needs and problems whilst either participating in the exercise activities, or delivering/supervising the program of exercises. The findings from the interview and observational studies provided us with insights into the requirements of the elderly whilst engaging in physical exercises and the potential benefits of digital games for their physical exercise and rehabilitation activities. We reported the pre-study #1 and findings in Pyae, Raitoharju, Luimula *et al.* (2016).

4.1.2 Pre-Study 2: Literature Review on Motivational Game Design for the Elderly

According to the Mayo Clinic (2015), motivation plays a vital role in successfully engaging in physical exercises, and it can be a significant barrier for the elderly to initiate physical exercise activities (Petersen, 2016). Justine, Azizan, Hassan *et al.* (2013) state that lack of motivation is associated with the elderly's inactivity or lack of engagement with physical exercise. Kravitz (2010) points out that elders' low motivation to participate in physical exercises can lead to low adherence and termination from regular exercise routines. Hence, in pre-study #2, we reviewed the literature pertaining to factors, which can have an influence on the elderly's motivation for undertaking physical therapeutic exercises. Based on the findings from pre-study #2, we proposed motivational game design guidelines for elderly players of digital games, with particular application to physical exercise and rehabilitation programs. During this project, these design guidelines provided useful insights into the design and development of digital games for elderly users to promote their physical exercise activity including rehabilitative training. We also discussed with healthcare

professionals as well as elderly participants to make these proposed design guidelines are suitable for both healthy elderly people and the elderly who need rehabilitation training. We reported more details of the study as well as findings in Pyae, Mika, and Smed (2015).

4.1.3 Pre-Study 3: Usability Testing of Existing Games

In pre-study #3, we reviewed existing commercial games available in the market, including Nintendo Wii, Sony PlayStation, Microsoft Xbox, and Dance Dance Revolution. Based on this review, we found that most commercial games available in the market are neither designed for elderly users nor for their age-related physical exercise needs. This finding is also supported by the literature, including IJsselsteijn, Nap, and Kort (2007), Gerling, Livingston, Nacke *et al.* (2012), and Li, Xu, Tan *et al.* (2017). Pyae, Tan, and Gossage (2013d) also claim that most of the available games are not user-friendly for elderly players because they take no account, in either their technical or operational design, the age-related limitations of the functional and cognitive abilities of the elderly. For instance, whilst Nintendo Wii (Bieryla & Dold, 2013) and Microsoft Xbox games (Chiang, Tsai, & Chen, 2012) may show promise for use in physical exercises and rehabilitation, in operation most of them lack elderly-user-friendly game design, which takes into account the special needs of the elderly whilst engaged in physical exercises. As an example, Nintendo Wii's Sports games have the potential to train the elderly to improve their movements in a rehabilitation context (Chao, Scherer, & Montgomery, 2015). However, in practice, these games are not well-designed and cannot deliver customization or personalization for the elderly. The findings from this literature review highlight two key issues, firstly the failure of commercial digital games to grapple with elderly-specific design parameters, and secondly the urgent need for age-related game design guidelines and operational specifications tailored to the physical and cognitive needs of the elderly. These insights were crucial to the next stage of our project, the game development phase and to any future game development by others. The findings from this study are reported in Pyae, Luimula, and Smed (2016).

In this pre-study, we also evaluated the usability and usefulness of existing commercial games, as well as an in-house game developed by the Puuha Group, Finland (see Figure 4.1). For commercial games, we selected the Kinect-based Xbox Climbing game and PlayStation's Tennis game. For the in-house game, we selected Puuha Group's SportWall game. We tested the games with two groups of the elderly, currently residing in two different elderly service homes in Finland. The main objectives of the study are to investigate the usability of both commercial and in-house digital games for the elderly.

Based on the findings from this usability study, we identified important game design guidelines to ensure optimal usability for our future design, and for the further development of GSH games for the elderly. The detailed study design and procedures, as well as findings from the study, are reported in Pyae, Raitoharju, Luimula *et al.* (2016).

Figure 4.1 Usability Evaluation Session

4.1.4 Pre-Study 4: Usability Testing of Interactive Multimodal Input Devices for the Elderly

In the pre-study #4, we tested multimodal input devices for digital games to understand their usability for elderly players of digital games. We evaluated the usability of Microsoft Kinect motion-sensor, PlayStation's Move Controller, and webcam-based Extreme Reality motion detector. We conducted a usability and user experience study with 12 elderly participants at different elderly service homes in Finland. The findings from this pre-study #4 helped us understand the differences in the usability of commercial multimodal input devices available in the market, and provided insights into the selection of the most effective interaction device for our future game design and development. The findings from the study are reported in Pyae, Luimula, and Smed (2016).

4.2 Analysis and Design

In the analysis and design stage, we first collated all the data collected from the pre-studies. Then, we critically analyzed the data from each pre-study. From pre-study #1, we identified the usability and suitability of existing commercial digital games and selected them for evaluating with elderly participants in the future pre-studies. Furthermore, through observations and interviews, we identified the elderly-specific requirements for participation in physical exercises and rehabilitation. From pre-study #2, we gained insights into motivational game design guidelines for how best to design motivational games for the elderly to ensure they engage in regular physical exercise activities including rehabilitation exercises. From pre-studies #3, we conducted a usability evaluation and identified the usability issues specific to elderly users of existing commercial games. Also, through the review of commercial games, we gained insights into designing interactive digital games that can be entertaining, as well as effective for elderly users participating in digital game-based exercises. Through the evaluation of the in-house game by Puuha Group, we found significant barriers to the engagement of the elderly and identified major challenges which the elderly encountered whilst playing digital games. Furthermore, we identified their preferred types of digital games. Lastly, from pre-study #4, we gained insights into using an effective interactive input system that is both user-friendly and effective for the elderly. After the data analysis was completed, using our findings as a base-point, we brainstormed game ideas to design and implement an effective and efficient interactive digital game-based exercise system for the elderly. The analysis and design stage was iterative and we consulted with both healthcare professionals and design experts to ensure that the findings are relevant and applicable to the elderly users. Based on the findings from our analysis, we proposed game design and usability guidelines for the design and implementation of a digital game-based exercise system for the elderly. We outlined selected game design and usability guidelines in Table 4.1.

Table 4.1 Game Design and Usability Guidelines

Findings from Pre-studies	**Pre-study**	**Game Usability and Design Guidelines**
Familiar outdoor physical activities.	Pre-study #1	Game activity/Play
Familiar and real-world environment	Pre-study #1 and #2	Game environment
Uncluttered game interface	Pre-study #2, #3, and #4	Game interface
Senior-friendly visual elements	Pre-study #1, #2, #3, and #4	Game elements (e.g. graphics)
Senior-friendly game sound	Pre-study #3 and #4	Game sound
Effective and senior-friendly game instructions	Pre-study #2, #3 and #4	Game instruction
Senior-friendly audio and visual feedback	Pre-study #3 and #4	Game feedback
Positive and encouraging feedback	Pre-study #2	Game feedback
Level of difficulty in executing exercises	Pre-study #1 and #2	Game level
Achievable goal setting in an exercise program	Pre-study #1 and #2	Game goal setting
Social contact	Pre-study #1, #2, #3, and #4	Multiplayer and Social chat in the game
Senior-friendly rewards to encourage the elderly	Pre-study #1, #2, and #3	Game reward system
Senior-friendly interaction in gameplay	Pre-study #3 and #4	Game interaction
Senior-friendly multimodal input device Motion-based interaction device	Pre-study #4	Game interaction

Then, based on the findings from the analysis and design, we created a paper-based prototype for trial by elderly users. We also discussed our design and its real-world applications with other professionals with relevant expertise, in particular: game designers, interaction designers, and healthcare practitioners. Based on their

suggestions, a few iterations of prototyping were made to fine-tune and further refine the original prototypes. After designing the final paper-based prototype of the game, we then designed the graphical components of the game. This analysis and design stage of our study and proposed design guidelines are reported more details in multiple research articles, including Kattimeri, Qvist, Katajapuu *et al.* (2017), Luimula, Pitkakangas, Saarenpaa *et al.* (2016), and Pyae, Liukkonen, Luimula *et al.* (2017b).

4.3 Prototyping the Skiing Game

Based on the findings from the preliminary analysis and design stages as well as design guidelines (see Table 4.1), we then designed and implemented a digital game-based physical exercise for the elderly, which we called the *Skiing Game*, (see Figure 4.2). The main objective of the game is to promote elderly Finns' participation in physical exercise and rehabilitation activities through a fun and interactive gameplay as well as to provide game-based rehabilitation training for the elderly who need it. In prototyping, we designed a skiing-based game with snowy mountains and forest as the thematic context and visual background. The reason for choosing this type of sport for the digital game is that skiing is a popular activity among Finnish people including the elderly segment of the ageing population. The gameplay is simply based on steering a pair of skiing poles using the double pole skiing technique. This game is relatively easy and is a familiar mode of exercise for elderly Finns, most of whom have some previous experience of cross-country skiing. We used a traditional webcam-based motion-detection system to track players' movements during the game.

We used the Unity 3D game engine to design and develop the game, which requires a player to complete a simple calibration before the gameplay commences. When a player begins, he or she needs to ski through gates to reach the finishing line in a given time. There are many obstacles to avoid along the way, which can cause the player to fall. To control the game the player needs to hold their hands in the double pole skiing position to steer a pair of skiing poles, left and right. To move forward, the player needs to continuously move both hands forward and backward. To accelerate the movement, the player has to perform this action faster. The more the player moves both hands, the faster the movement becomes. It is important for the player to follow the skiing trail displayed on the screen. To move left or right, the player needs to move his or her body to the left or right. In the uphill and downhill sections of the game, the player needs to accelerate more or to slow down as required. When the player reaches the finishing line, the score screen will pop up, showing the player's time and the number of gates the

player successfully negotiated. More details are mentioned in Pyae, Liukkonen, Saarenp *et al.* (2016).

Figure 4.2 the *Skiing Game*

For the game interaction, we used a webcam with Extreme Reality (XTR3D) Technology to track the player's upper-limb movements. Extreme Reality includes technology that supports software-based motion analysis. It can control any computing device by using a traditional web-camera (Extreme Reality Technology, 2015). XTR3D includes a motion capture engine that detects the 3D position (X, Y, and Z) of a player's skeletal position just in front of the camera in every frame. After that, it creates a live 3D model of the player that is analyzed by the software to recognize the gestures from the skeletal positioning of the player.

4.4 Summary

In this chapter, we summarised the four pre-studies conducted in the requirements-gathering stage and referred the reader to the Appendix, where the papers are described in detail. Based on the findings from the pre-studies, we then analyzed the required technical parameters and operational specifications and from those designed a digital game-based physical exercise for the elderly, which we named the *Skiing Game*, and then followed up with the development of a functional prototype of the game.

Chapter 5
Usability Studies

This chapter outlines the usability evaluation of the *Skiing Game* conducted in Finland with elderly Finnish participants, as well as a cross-country usability study of the game conducted in Japan with elderly Japanese participants. The participant recruitment, methodology, study design, data collection methods, analysis, and findings from both the Finnish and Japanese studies are reported in this chapter.

5.1 The Finnish Usability Study

Firstly, we evaluated the *Skiing Game* in Finland with 21 elderly Finnish participants to investigate elderly Finns' user experiences during the gameplay, with an emphasis on the usability of the game, and the usefulness of digital games for that age group's physical exercise needs and capabilities. The elderly who participated in the pre-studies were excluded from this Finnish usability study. This usability study was undertaken at an elderly service home in Turku, Finland. A total of 21 elderly participants (M=7, F=14, Average Age =76) were recruited for the study. The participant selection was based on specific criteria, including limiting selection to those aged between 65 and 85 years. Their health was required to be stable, and they needed to be physically and mentally capable of using the game. Those with neurological or cognitive deficits were excluded. Any who were wheelchair-bound were also excluded from the study because the game requires players in the standing position for the duration of the gameplay. Participants needed to be able to stand for at least 15 minutes and to walk 10 meters without the need for support from a person or an invalid aid, such as a walking stick. The physiotherapist from the elderly center carefully selected the elderly participants so they met these stipulated study criteria. We also obtained written consent from everyone prior to participation in this study.

5.1.1 Procedures

The usability study includes three stages: pre-study, in-study, and post-study respectively. Before a particular elderly participant played the game, a researcher asked him or her the pre-study interview questions, which cover demographics, their social and physical activities, and their perceptions and prior experiences in playing digital games. These questions are elaborated in Pyae, Liukkonen, Luimula *et al.* (2017b). Then, the player went through a game tutorial session about how to play the game guided by a researcher. It was followed by the gameplay session. After playing the game, a

researcher asked the participant the post-study interview questions, which include in-game and post-game user experiences, the usability of the game, the perceived usefulness, ease-of-use of the game, and general interview questions about their gameplay. During the in-study, we observed all the participants' gameplay and interaction experiences by using note-taking method. In all three stages, we encouraged the elderly participants to take a short break from the session if required. In this study, the "*Finnish*" language was used to communicate with the elderly participants. Figure 5.1 shows an elderly participant playing the *Skiing Game*.

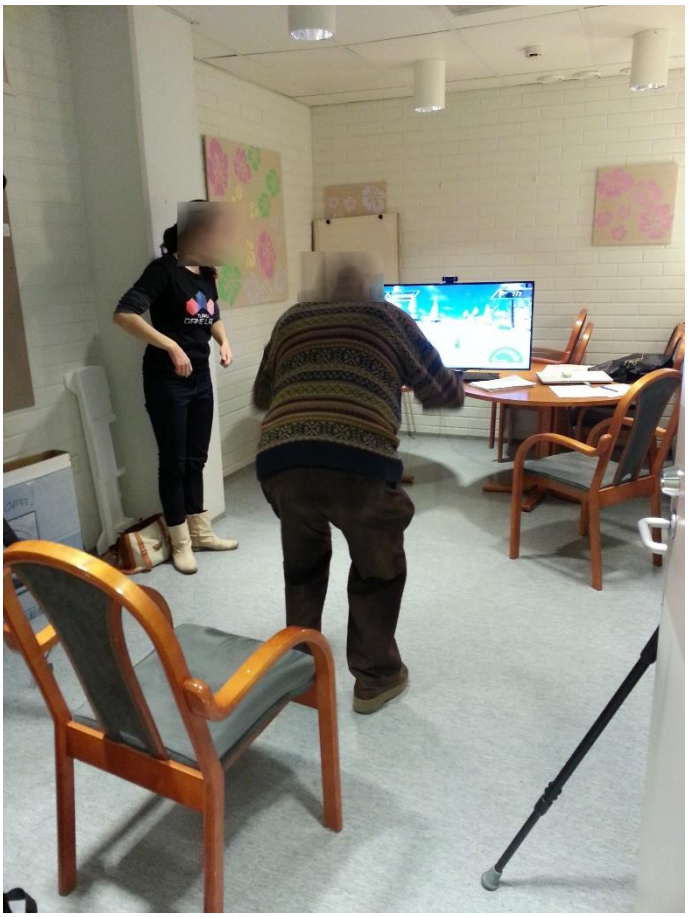

Figure 5.1 The Finnish Usability Study

For this project, we developed and used the pre-study interview questions to investigate the elderly participants' demographics, social and physical exercise activities, and their perceptions and prior experiences in playing digital games before the in-study session. Regarding the elderly participants' user experiences in the gameplay, we used the Game Experience Questionnaire (GEQ), developed by IJsselsteijn, Kort, and Poels (2017). We used a 5-point Likert scale ranging from "*Not at all (0)*" to "*Extremely (4)*" for GEQ. To investigate the usability of the *Skiing Game*, we used the

System Usability Scale (SUS), which is easy and simple for the elderly to understand and is based on ten-item scales for subjective assessment of the usability of a particular system (Brooke, 2013). For SUS questions, we also used the 5-point Likert scale, which ranges from "*Strongly disagree* (1)" to "*Strongly agree* (5)". In addition, we modified the SUS questionnaires to better measure the achievement of the stipulated objective of the study. We developed the general post-study interview questions based on the Senior Technology Acceptance & Adoption Model (STAM) (Renaud & van-Biljon, 2008). All the paper-based and face-to-face interview questions used in this study are discussed in detail in Pyae, Liukkonen, Luimula *et al.* (2017a), Pyae, Joelsson, Saarenpää *et al.* (2017), and Pyae, Liukkonen, Saarenp *et al.* (2016).

5.1.2 Analysis and Findings

The findings from the pre-gameplay study show that the elderly Finnish participants are active and have positive attitudes towards engaging in regular physical exercises. The majority of elderly participants did not have prior experience of playing digital games, and the findings from the pre-gameplay study revealed that they not only had negative attitudes towards digital games but also held misconceptions about playing digital games (Pyae, Liukkonen, Luimula *et al.*, 2017a). By way of illustration, they believed that digital games were only for younger people and that playing digital games could negatively impact their health.

After the gameplay, the elderly participants reported that they found the *Skiing Game* to be both user-friendly and a useful game which they judged would have sufficient interest to motivate them to continue the commitment to an ongoing program of exercise. According to the findings, the elderly Finnish participants had moderately positive experiences whilst playing the *Skiing Game*. Their in-game experiences were relatively positive and were correlated with their post-game positive experiences, as expected. Noticeably, the findings show that their attitudes towards digital game-based physical exercises changed positively after they had played the game. Their motivation whilst playing this digital game-based exercise was relatively high. They also showed a strong interest in playing digital games as a form of exercise in the future. They stated that digital game-based exercises could be an effective way of exercising for them. They indicated that digital games could definitely be a viable alternative solution when they could not access conventional physical exercises due to factors such as bad weather, health conditions, distance to be traveled to the nearest venue, or lack of facilities in their vicinity. They showed interest in having digital games installed in elderly service

homes. They also recommended that digital games be regarded as a useful tool for exercising at home. The findings from the study show that digital game-based exercise is a promising alternative mode of exercise for elderly Finnish people. We reported the Finnish elderly participants' user experiences in playing the *Skiing Game* in Pyae, Liukkonen, Luimula *et al.* (2017b). We also reported the Finnish elderly people's attitudes and motivation towards digital game-based exercise activity in Pyae, Liukkonen, Luimula *et al.* (2017a).

5.2 The Japanese Usability Study

In Japan, we conducted a cross-country usability study of the *Skiing Game* with 24 elderly Japanese (M=12, F=12, Average Age = 72). The elderly Japanese participants were recruited with the help of the officers from the Sendai Well-being center in Japan. The criteria for inclusion of participants were the same as for the Finnish usability study of the *Skiing Game* (see Section 5.1). The main objective of this study was to investigate whether the *Skiing Game* is usable, user-friendly, and useful for elderly non-Finnish users living outside of Finland. In addition, our goal was to determine whether digital game-based physical exercise could also be used as an alternative solution for elderly non-Finns engaged in physical exercise. In the Japanese usability study, we applied the same research design, methods, procedures, data collection tools, and analysis applied in the Finnish study. This study took place at the Sendai Well-being center in Japan. Both the Finnish and Japanese researchers were involved in the study, and the '*Japanese*' language was used to communicate with the elderly Japanese participants.

The findings show that all the elderly Japanese involved in this study are physically and socially active. However, 12 out of the 24 participants had never previously played digital games. While some of these participants held misconceptions about digital games, other participants showed a marked interest in digital games. Of the 12 participants who had prior experiences in playing digital games; however, they never played digital games for exercise purposes as well as digital games that require bodily movements to play. The findings from the Japanese usability testing show that the participants had a moderately positive experience during the gameplay. They also judged the *Skiing Game* to be an easy game to play, which they would willingly recommend to others. Although they had somewhat negative attitudes towards digital games prior to the gameplay, the participants reported a more positive attitude after they have played the *Skiing Game*. They also reported they believed game-based physical exercises could be both effective and useful for enhancing their physical fitness. This

interest in playing digital games was reported across all venues, both at the elderly service centers and in their own homes. They agreed that digital game-based exercises could be a beneficial alternative mode of easily accessing exercise. They also mentioned that they would play digital games as a form of physical exercise in the future. Based on the findings from this study, we strongly argue that digital game-based physical exercises are indeed both a promising tool for enhancing elderly Japanese people's experience of physical exercise and an alternative way of ensuring they remain motivated to continue engagement with physical activities. The findings and discussion from the Japanese study are reported in Pyae, Liukkonen, Saarenp *et al.* (2016). Figure 5.2 shows the Japanese usability study.

Figure 5.2 The Japanese Usability Study

5.3 The Comparative Study

Based on the findings from the analysis of data from both studies, we also conducted a comparative study to understand the differences between the elderly Finnish and Japanese participants in their user experiences, reported usability of the game, and perceptions of digital games as an alternative way of exercising. Firstly, prior to the gameplay, we found that the elderly Japanese participants had more positive attitudes towards digital games, compared with the elderly Finnish participants. Regarding the participants' responses to the usability of the *Skiing Game*, we found that both elderly groups responded quite positively, and there was no difference between the two groups. Similarly, both elderly groups had relatively positive experiences, both

in-game and post-game; whilst the elderly Finnish participants had slightly more positive experiences than their Japanese counterparts.

With regard to the post-gameplay session, we found that both elderly groups had similar positive attitudes towards the game. The findings show that elderly Japanese participants have more positive attitudes towards playing digital games after the gameplay than their Finnish counterparts. The findings also revealed that the elderly Japanese participants believed that they are more likely to play digital games in the future and, that playing digital games was now regarded by them as an attractive alternative solution for ongoing engagement with physical exercises. They also indicated that it could be beneficial for their physical health. In contrast, the elderly Finnish participants suggested that playing digital games could be an alternative solution for them when they do not have access to their primary mode of physical exercise. The elderly Finnish participants also recommended digital games as most useful for home-based exercise activity when they are unable to visit elderly service homes.

Based on these findings from both the Finnish and Japanese usability studies, the *Skiing Game* is clearly judged to be an easy and user-friendly game for both elderly groups. The user experiences of the elderly Finnish and Japanese participants during the gameplay were relatively positive. In addition, the elderly participants in both groups who had previously held misconceptions about the digital game subsequently changed their attitudes so that they viewed it more positively after completing the gameplay. As a consequence, they were more interested in playing digital games in the future. Furthermore, we found that digital games have the potential to be used as an alternative solution to promote the elderly's physical well-being, both in Finland and Japan, through the integration of the games into a program of regular exercises. Digital games are a viable alternative approach to motivating ongoing engagement with physical exercise activities, especially for the elderly Finnish participants, as well as a promising tool for home-based physical exercises. The findings and discussion from the comparative study are reported in Pyae, Joelsson, Saarenpää *et al.* (2017).

5.4 Usability Recommendations

In this investigation, through observational studies and general interview sessions, we evaluated both elderly Finnish and Japanese participants' user experiences and reported usability issues whilst playing digital game-based exercise. We observed both the Finnish and Japanese usability studies by using two video recorders (front and back views) and taking notes to record user experiences. Then, we assessed the

individual participant's accomplishment of a particular game task (e.g. skiing activity). We also conducted post-study general interview sessions to investigate the participants' user experiences during the gameplay, as well as their feedback and suggestions for improvements in the technical and human elements of the game design and operation. Based on the findings from a collated qualitative analysis of all aspects of the study- as recorded through observation, note-taking, and interviews- we identified the barriers to ease of use and the challenges encountered by both elderly Finnish and Japanese participants. Then, based on what we learned from the studies, we framed recommendations on how best to improve the games' usability. All of this data and the resulting insights will be useful for our future research, as well as a practical benefit to practitioners in related areas involved in designing and developing digital games for the elderly (see Table 5.1). These usability recommendations are also in-line with the previous findings from the pre-studies. Hence, the usability findings from both the Finnish and Japanese studies confirm that these guidelines are important to take into consideration while designing digital games for elderly people for physical exercise activity. These findings, discussion, and recommendations for improvements to the usability of digital games for elderly users are elaborated and reported upon in detail in Pyae, Joelsson, Saarenpää *et al.* (2017).

Table 5.1 – Usability Recommendations

Category	Lessons Learned
Game Context	Elderly players prefer real-world game context, which is relevant to be simulated during the game.
Game Play	Elderly players prefer real-world activities to be designed into the game.
Game Feedback	Elderly players prefer positive feedback during the game regardless of their performance and achievements.
User Experiences	It is important to minimize the physical risks of elderly players during the gameplay.
	It is important to minimize elderly players' frustration during the gameplay.
	It is important to minimize cognitive complexities within the game design and operation, especially for novice elderly players.
	It is important to minimize elderly players' motion sickness during the gameplay.
	It is important to create a sense of achievement for novice elderly players.
Category	**Lessons Learned**

User Interface	Providing visual cues and voice-based instructions should be taken into consideration when designing games targeted to elderly players.
	Controller-free interaction was judged both easy to perform and effective for elderly players.

5.5 Summary

In this chapter, we summarised the usability studies of the *Skiing Game* conducted in Finland with elderly Finnish participants and in Japan with elderly Japanese participants. The research design, methods, procedures, data collection tools, and analysis used in both studies were discussed. In addition, we reported the findings from the comparative study between the Finnish and Japanese usability studies. These findings are reported in more detail in the papers referenced. Furthermore, we detailed the recommendations derived from the findings to assist designers to improve the usability of digital game-based exercises for the elderly.

Chapter 6
Summary of Publications

In this chapter, the research papers resulting from this study are described, along with the provision of the relevant sourced references from the literature review. Furthermore, these papers are cross-referenced as relevant throughout the previous chapters (from Chapter 2 to 5) and described in more detail in this chapter.

6.1 Article 1: Serious Games and Active Healthy Ageing: A Pilot Usability Testing of Existing Games

In this research article Pyae, Raitoharju, Luimula *et al.* (2016), we reported the findings from the pre-studies, which provided a careful mapping of the existing games, an systematic literature review of digital games for elderly users, a comprehensive review of existing commercial games and technologies, and the parameters for the thorough interviews, and observational studies conducted at the elderly service homes in Finland. The literature review includes serious games, exergames, and gamification for the elderly's physical, rehabilitation, social, and cognitive well-being. The review of existing digital games covers 30 commercial games, which were tested and evaluated using various methods by the health informatics students from the Turku University of Applied Sciences (TUAS) Finland, as well as researchers from the Turku Game Lab, and therapists from the elderly service homes involved in the research. The main purpose of the study was to understand the usability and usefulness of these commercial digital games for elderly users. Then, the students and researchers conducted observations of, and interviews with, the elderly participants at the elderly service homes in Finland to understand any reported issues with the design and operation of the games and any stated unmet requirements regarding the mode and effectiveness of delivery of exercise and rehabilitation regimes. The findings from this study provided insights into the potential of existing commercial digital games for meeting the exercise and rehabilitation needs of the elderly with varying physical and cognitive abilities. Based on the findings from the pre-studies, we conceptualized the *Gamified Solutions in Healthcare* (GSH) project. Then, we scheduled the project timeline and research activities, which would be required to be carried out during the GSH project. In this research activity, the author contributed to the literature review, interviews and observations, and analysis of data. In the manuscript, the author contributed as the main author in the literature review, method, data analysis, and discussion.

6.2 Article 2: Rehabilitative Games for Stroke Patients

This research article represents the findings from the literature review in terms of how best to understand motivational game design and how to most effectively incorporate the suggestions from the elderly users for improvements in design and operation of the games for incorporation into programs of physical exercises (Pyae, Mika, & Smed, 2015). Firstly, a literature review was conducted to understand the factors influencing the elderly's motivation in participating in physical and rehabilitative exercises. Based on the findings from the literature review, we proposed a set of motivational factors necessary to engage the elderly in physical exercises and rehabilitation. Based on these motivational factors, we proposed guidelines for the most effective and efficient design for digital exercise games for elderly users. These proposed motivational game design guidelines, arising from insights gleaned from this completed study, provided us with the necessary parameters for optimal engagement with the exercise by the elderly. Although this article is limited to motivational factors for elderly stroke patients, we ensured that the design guidelines we proposed in this article are also relevant to healthy elderly participants in doing physical exercise activity.

In this paper, we also reported the findings from the pilot study of the usability of existing commercial and in-house games, including the Microsoft Xbox Sports game, PlayStation Sports game, and the SportWall game by Puuha Group. In addition, we reported the findings from the evaluation of game interactive devices for elderly users, including Microsoft Kinect, PlayStation Move controller, and the Xtreme Reality webcam-based motion detector. We evaluated both digital games and interactive devices with elderly participants in Finland. The findings from this study can help us better understand the potential, usability, usefulness, and suitability of existing commercial digital games for physical exercise, across both in-house games, and game controllers for elderly players. They were insightful into designing digital game-based physical exercise activity for the elderly. In this research activity, the author contributed mainly to the literature review and pilot usability study, while contributing to the manuscript as the main author particularly in the literature review, method, data analysis, and discussion.

6.3 Article 3: Pre-studies on Using Digital Games for the Elderly's Physical Activities

In this research article Pyae, Luimula, and Smed (2016), we presented the pre-studies of the GSH project. The first pre-study is a literature review of game designs used for motivating the elderly to engage in physical exercise. In the second pre-study, we reviewed the existing commercial games to understand the games' design in terms of how best to engender elderly participants' motivation to commence and then continue to use the games. Findings from pre-studies #1 and #2 helped us understand the potential use of existing games and the applicability of their technologies in our own future game development. In pre-study #3, we reported upon the outcomes of the evaluation of the Microsoft Kinect motion sensor using elderly participants in Finland. In this study, the elderly participants went through a tutorial consisting of different tasks using the Kinect Sensor. The findings from this study provided us with insights into how best to utilise the Kinect sensor with elderly players of digital games. Lastly, in pre-study #4, we reported the findings from the evaluation by elderly participants of existing digital games. Based on the findings from all of these pre-studies, we proposed recommendations of how best to design digital games to better promote engagement by the elderly in physical activity tailored to their needs. These findings also gave rise to valuable insights into elderly users which we applied to our own design and development of the *Skiing Game* for the GSH project. In this research activity, the author contributed in all stages of pre-studies, while contributing to the manuscript as the main author particularly in the literature review, method, data analysis, and discussion.

6.4 Article 4: Investigating the Finnish Elderly People's Attitudes and Motivation towards Digital Game-based Physical Exercises

In this research article Pyae, Liukkonen, Luimula *et al.* (2017a), we presented the findings from the usability testing in Finland of the *Skiing Game* with 21 elderly Finnish participants. The main objective of the study was to understand elderly Finns' attitudes towards digital game-based exercises and their motivation during the gameplay. We investigated and compared elderly Finns' attitudes towards traditional physical exercises, as well as towards digital game-based exercises. In this study, we also investigated elderly Finns' motivation for participating in the study and their reasons for playing digital game-based exercises, thus further exploring their feedback and

comments. The findings suggest that elderly Finns' perceptions of digital game-based physical exercises were positive, and they recognised its potential for use both at elderly service homes and in a home-based setting. In this research activity, the author contributed to participant recruitment, research method, data collection, and analysis, while he contributed to the manuscript preparation as the main author particularly in the literature review, method, analysis, and discussion.

6.5 Article 5: Investigating the Finnish Elderly People's User Experiences in Playing Digital Game-based Skiing Exercise: A Usability Study

In this research article, Pyae, Liukkonen, Luimula *et al.* (2017b)we reported the findings from the usability evaluation of the *Skiing Game* conducted with 21 elderly Finnish participants. The main objective of the study was to investigate the usability, user experiences, and usefulness of digital game-based exercises for elderly Finns. We reported the participants' feedback on the usability of *Skiing Game*, and then their in-game and post-game user experiences of playing the *Skiing Game*. We then investigated the usefulness to elderly participants of digital game-based exercises as an alternative mode of engagement with exercise. We also evaluated the potential of digital game-based physical exercises to maintain ongoing interest by the elderly in physical activity. The findings from the Finnish usability testing of the *Skiing Game* helped us understand the potential appeal of digital games for elderly Finns to engage with physical exercises across a range of settings, both at elderly service homes and in their own homes. In this research activity, the author contributed to participant recruitment, study design, method, data collection, and analysis. Furthermore, the author contributed to the manuscript preparation as the main author particularly in the literature review, method, data analysis, and discussion sections respectively.

6.6 Article 6: When Japanese Elderly Play a Finnish Physical Exercise Game: A Usability Study

In this research article Pyae, Liukkonen, Saarenp *et al.* (2016), we reported the findings from the usability study in Japan with 24 elderly Japanese. The main objective of the study was to investigate the usability, user experiences, and usefulness of digital game-based exercises for elderly Japanese. Furthermore, we were interested in studying elderly non-Finnish participants' feedback on the usability of the *Skiing Game*. We also

investigated whether digital game-based exercises are promising and useful for fostering in elderly Japanese participants the motivation to commence and maintain engagement with regular physical activities. The findings confirmed that the potential benefits of digital game-based exercise -as perceived by elderly Finns- was also recognised by elderly non-Finnish users outside of Finland. In this research activity, the author contributed to the literature review and analysis of data. For manuscript preparation, the author contributed as the main author particularly in literature review, research design, data analysis, and discussion sections respectively.

6.7 Article 7: Lessons Learned from Two Usability Studies of a Digital *Skiing Game* with Elderly People in Finland and Japan

In this research article Pyae, Joelsson, Saarenpää *et al.* (2017), we reported the findings from the comparative analysis of the Finnish and Japanese usability evaluations of the *Skiing Game*. The main objective of this article is to report on the investigation into the differences between two elderly groups, the Finnish and Japanese in terms of their perceived and objectively measured judgments regarding the level of usability, the negative or positive nature of their user experiences, and the reported usefulness of digital games for commencing and maintaining a regular exercise or rehabilitation regime. More importantly, in this article, we reported the details of what was learned about how best to enhance both the technical design and the quality of the participants' experience in order to improve game usability. These lessons arose from our close analysis of the participant observations and interviews from both the Finnish and Japanese usability studies. We also presented our proposal for future projects to conduct a further investigative study into various human and operational aspects of game design. In addition, the technical issues thrown into sharp focus by problems discovered are discussed during our analysis of the two usability studies conducted in Finland and Japan. In this manuscript, the author contributed to the literature review, comparative analysis, and discussion.

6.8 Summary

In this chapter, we listed all the publications resulting from this study. A brief description of each is also provided by referencing the relevant research articles.

Chapter 7

Conclusion

7.1 Concluding Remarks

In this thesis, our literature review suggested that previous studies of digital games had established their use for promoting physical exercise activities through fun and engaging gameplay. However, the literature confirmed that most existing commercial games are not user-friendly for the elderly whose age-related limits on functional and cognitive abilities failed to be adequately taken into account. It also highlighted the gaps in the research into digital games for the elderly. This made it clear that there was an urgent need to undertake further usability studies so that we can design user-friendly and useful digital games for promoting the physical well-being of the elderly. Furthermore, the literature highlighted that although there was on-going research in Finland; however, there is a need for more studies to be undertaken to understand the elderly's user experiences in digital gameplay. It was also unclear whether digital games could be a useful and alternative tool for promoting the physical health of the elderly. Thus, this research focused only on elderly Finns' user experiences, motivation, attitudes towards digital game-based exercises, and their perceptions of digital games as an alternative way for physical exercise. Also, we aimed at understanding non-Finnish elderly's user experiences in digital games with the purpose of marketing the Finnish games into the global market particularly for digital games for the aged group. To bridge these research gaps we formulated for our investigation four research questions to assess the usability, user experience, and usefulness of digital games for not only the elderly Finns but also elderly non-Finns living outside of Finland.

RQ1: What are the user experiences of elderly Finns in playing digital game-based physical exercise activity?

With the first research question (RQ1), we aimed to understand elderly Finnish users' experiences in playing digital game-based exercises. To address this research question, in Chapter 2, we reviewed the literature about the elderly's user experiences whilst playing digital games, as well as the benefits of digital games for the elderly's physical well-being. In Chapter 3, we described the mixed methods approach encompassing both qualitative and quantitative research methods to investigate elderly Finns' user experiences whilst playing digital games. In Chapter 4, we conducted pre-studies to understand elderly users' experiences whilst playing commercial digital games, followed by the functional development of our *Skiing Game,* which was designed

to address the shortfalls identified in the application of existing commercial games. Then, in Chapter 5, we conducted in Finland the usability evaluation of the *Skiing Game* with elderly Finnish participants.

This research question was answered by the following findings from the usability study of the *Skiing Game*, which reported in brief then elaborated upon previous findings in more detail in Pyae, Liukkonen, Luimula *et al.* (2017b) and Pyae, Liukkonen, Luimula *et al.* (2017a). Firstly, the elderly Finnish participants suggest that the *Skiing Game* is easy to operate and was perceived by them as a user-friendly game. Secondly, before they participated in the *Skiing Game*, most of the elderly Finnish participants had no prior experience with playing digital games, and they also had a negative attitude towards, and misconception about digital games. However, their attitudes changed positively after they had played the *Skiing Game*. In addition, they enjoyed the gameplay and expressed an interest in using digital games in the future. Regarding their in-game experiences, they reported a positive affection while they were playing the game. Furthermore, as expected, their positive affection during the gameplay was found to correlate with their positive experiences after the gameplay. The overall experiences of the elderly participants in the gameplay were noticeably positive. While they were relatively motivated in the gameplay, they also reported they saw a potential use for digital game-based exercises in the future. These findings are in-line with the existing literature. For instance, Wiemeyer and Kliem (2011) state that compared with traditional physical exercise interventions, digital game-based exercises can provide playful, entertaining, engaging, and fun activities for the elderly. This claim is supported by studies, which found digital games can create positive psychological effects on players, including improvements in engagement, attention, and self-esteem. Zhang and Kaufman (2015) also claim that digital games are designed to be fun for players, and can be used as an enjoyable tool for physical and cognitive training. The positive effects of digital games on elderly players were also reported by other researchers, including Aarhus, Grönvall, Larsen *et al.* (2011), Molina, Ricci, de Moraes *et al.* (2014a), Kappen, Mirza-Babaei, and Nacke (2018), and Pyae, Tan, and Gossage (2013d).

RQ2: What are elderly Finns' perceptions of playing digital games as an alternative way for undertaking a physical exercise activity?

For the second research question (RQ2), we studied elderly Finns' perceptions of digital game-based exercises as an alternative form of physical exercise. To answer this research question, the literature review in Chapter 2 highlighted the established potential of digital games as a tool to improve physical well-being by delivering effective

and efficient physical rehabilitation and functional training activities. We described the research methodology in Chapter 3 to address this research question. Then, in Chapter 4 we explained how we conducted pre-studies followed by details about the analysis, design, and development of a functional prototype. In Chapter 5, we described how we conducted the usability evaluation of this prototype which we named the *Skiing Game.*

This research question was addressed by the findings from the usability study of the *Skiing Game*. It was also reported in Pyae, Liukkonen, Luimula *et al.* (2017b). In this study, elderly Finnish participants confirmed that playing digital games is fun and entertaining, as well as useful for improving their general mobility and the range of their physical movements. They recommended that digital games be used not only as an entertainment tool but also as an effective mode of exercise. The majority of them recommended using it when they do not have access to traditional physical exercises. For instance, if the elderly do not - for various reasons, perhaps bad weather-have access to their usual facility such as an elderly service home, which offers traditional physical exercises, then they agreed digital game-based exercises can be a useful and effective alternative. They also showed an interest in using digital games as a home-based exercise activity in the future. These findings are also consistent with the prior studies claiming that digital games are beneficial for the elderly wishing to improve not only their physical abilities but also their cognition. For instance, Rendon, Lohman, Thorpe *et al.* (2012) state that digital games are useful for improving the physical and functional abilities required by the elderly in everyday living. Oesch, Kool, Fernandez-Luque *et al.* (2017) note that digital game-based exercises are an attractive alternative for those in the older age group wishing to increase their motivation to engage in self-regulated exercises. Palacio, Acosta, Cortez *et al.* (2017) state that because playing digital games reinforces abilities and skills such as concentration, memory, coordination, memory, and reaction speed, they seem to be beneficial for the elderly. Amongst prior studies, which reported that digital games can be used for physical rehabilitation, fitness exercises, and social activities for the elderly, we consulted Hanneton, Varenne, and Hanneton (2009), Theng, Teo, and Truc (2010), Brox, Evertsen, Åsheim-Olsen *et al.* (2014), and Gerling and Mandryk (2014).

RQ3: What are the usability challenges encountered by the elderly Finns whilst engaged in a digital game-based physical exercise activity?

For the third research question (RQ3), we investigated the usability challenges encountered by the elderly whilst playing digital game-based exercises. In Chapter 2, we identified the gaps in existing research needing to be addressed in relation to the ease of

usability of digital games for the elderly. For instance, Floyd, David, and Ashot (2015) point out that the design of digital game-based exercises is a difficult intertwined challenge requiring the combining of digital games technology and players' physical effort. To answer this research question, in Chapter 5, we detailed how we conducted in Finland and Japan two usability studies of the *Skiing Game* with elderly Finnish and Japanese participants. The findings from the usability studies of the *Skiing Game* addressed this research question and these findings were also reported in Pyae, Joelsson, Saarenpää *et al.* (2017). In both the Finnish and Japanese usability studies of the *Skiing Game*, we observed the problems with usability and the physical and cognitive challenges experienced by the elderly participants. It should be noted that we also identified elderly participants' positive user experiences whilst playing the game. Based on these usability observations, we carefully formulated recommendations for improving usability (see Chapter 5). These recommendations should greatly assist with the future design and development of digital game-based physical exercises for the elderly, not only in Finland but also in other countries. We are confident that this broader international user pool will prove to exist as our comparative evaluations highlighted the commonalities across various cultural groups in Finland, Japan, and Singapore which we predict will be similarly applicable to other countries. These recommendations for the improvements in the usability of digital games could be useful for not only game designers but also practitioners within fitness and rehabilitation services. More details about these recommendations for improvements in digital game usability were reported in Pyae, Joelsson, Saarenpää *et al.* (2017). Some of the usability guidelines are consistent with the existing literature detailed by several researchers, in particular, IJsselsteijn, Nap, and Kort (2007) and Gerling, Livingston, Nacke *et al.* (2012).

RQ4: What are the differences in user experiences, usefulness, and usability of digital game-based physical exercise activity between the Finnish and non-Finnish elderly people?

Research question four (RQ4) was framed to investigate differences as perceived by participants and objectively measured regarding user experiences, usefulness, and usability of digital game-based exercises when comparing elderly Finnish and non-Finnish users. In Chapter 1, in order to address this research question, we framed as one objective for the *Gamified Solutions in Healthcare* project a measure of the understanding by elderly non-Finnish users of the digital games designed by the Turku Game Lab, an evaluation of the quality of their user experiences, followed by a comparison with elderly Finnish users' experiences. We described the research methods

in Chapter 3, and detailed aspects of our analysis, design, and development in Chapter 4. In Chapter 5, we described the parameters of the usability studies of the *Skiing Game* conducted with elderly Finnish and Japanese participants.

Based on the findings from the comparative study between the Finnish and Japanese usability studies of the *Skiing Game*, we concluded that the *Skiing Game* is an easy to use and user-friendly game for elderly participants both in Finland and Japan. We also found that there are no differences in usability and user experience between these two groups. Both groups of elders had a relatively positive experience and had shown an interest in playing digital games in the future. The only difference we found during the study is that elderly Japanese participants are willing to use digital games as an alternative way of exercising while elderly Finnish participants reported they were more likely to use digital games when they do not have access to traditional exercises. The findings also show that digital game-based exercises show promise for both elderly groups to successfully engage in physical exercise activities. These findings are useful for our future study in GSH to expand the market for the Finnish digital games into foreign countries and to promote the game as an effective and efficient mode of enhancing elderly people's physical well-being worldwide.

In conclusion, digital games for delivering physical exercises to elderly users is a broad research area. The findings from this study not only support the existing literature (Pyae, Joelsson, Saarenpää *et al.*, 2017) but also create new insights for future studies in the design and development of digital game-based exercises for the elderly. Furthermore, these findings can help researchers, healthcare practitioners, policymakers, and students, who are working in related areas particularly in the context of Finland, to better understand and support the potential for the use of digital games to promote the elderly's physical activities. It also provides helpful advice for expanding the market for Finnish games into the international sphere. Last but not least, using digital games to promote the physical well-being of the elderly is beneficial in terms of assisting them to better adapt to their inevitably increasingly digital society. Furthermore, by using digital games, we can provide an alternative solution to the question of how best to promote elderly people's quality of life through an enjoyable digital activity.

7.2 Research Implications

Based on the findings from this study, policymakers, healthcare practitioners, and caregivers, especially those in Finland, could take into account our

recommendations for using and introducing digital games to elderly Finns as an additional or alternative exercise intervention, especially in the context of physical rehabilitation and activities at elderly service homes. Researchers, healthcare practitioners, and policymakers in Finland can also consider designing home-based exercise games for elderly Finns to promote their daily physical activities. In this study, we notice that the elderly who had negative attitudes towards digital games have after the gameplay positively adopted this mode of delivery. These findings can help practitioners and researchers gain insights into how best to introduce user-friendly digital games to elderly people to assist them to regularly engage in physical exercises through gameplay. The findings from the comparative study also confirm that digital games for elderly Finns have shown potential for global use by older age groups. It also offers insights for the Finnish game industry into how best to take into account not only their national market but also international markets for their digital game-based exercises. More importantly, the recommendations for improving usability which we report in this study can assist designers, practitioners, and researchers all over the world to gain insights into enhancing their processes for designing and developing digital games for physical exercises for the elderly. Lastly, the findings and suggestions for improvements in the design and operation of digital games outlined in this study can provide useful input for future research into the most effective and efficient use of digital games to better promote the elderly's physical well-being.

7.3 Limitations of the Study

Firstly, the sample size in the study is relatively small due to limited time and restricted resources, resulting in an inability to recruit a larger number of elderly participants in Finland and Japan. In this study, although we evaluated a number of commercial games and in-house games in the pre-studies, we used only the *Skiing Game* for the usability studies in Finland and Japan. The suggestions in this study for improvements to usability are targeted only to practitioners and designers to take into consideration when improving the design and operation of digital games for the elderly's physical exercises followed by rehabilitation to a certain extent. Further studies are recommended to convert these usability lessons into more specific design guidelines, which should be followed up with an evaluation of the improved games' usability. The perceptions of elderly people regarding digital games are only limited to the Finnish and Japanese contexts. In this study, we excluded the data from video observation in the analysis. One limitation of the study is that the *Skiing Game* was not

designed for multiplayers although the findings from the pre-studies suggested it. Hence, in the future study, we should focus on social gameplay for the elderly to promote their social contact and activity. Also, one of the limitations is that half of the Japanese elderly participants in this study have prior experiences in playing digital games; however, they never played exergames or digital games with bodily movements in the gameplay. The other limitation of the study is that although *Skiing Game* we used in this project is targeted for both healthy elderly people and the elderly who need rehabilitative training, the elderly in both Finish and Japanese testing were generally healthy participants. Hence, the rehabilitative purpose of the game is still required to further investigate as future work. Also, the rehabilitation purpose of the game in this study is limited to the context of stroke rehabilitation. However, it does not affect our initial research aims to investigate the Finnish elderly people's user experiences in playing digital games for their physical health. The findings from the study helped us answer the research questions formulated in the study. We suggest conducting further studies in different countries to obtain a broader understanding of the elderly's perceptions of digital games.

7.4 **Future Work**

In future work, we will continue research and trials of digital games designed to enhance the quality of life of the elderly. These enhancements will incorporate applications for physical, social, and cognitive well-being. More importantly, the next phase of the study is to evaluate the *Skiing Game* with the elderly who need rehabilitation training and examine if digital game-based approach is usable and useful for this age group with specific needs. We will also conduct a number of cross-country studies in different regions of the world, including Europe, Asia, Asia-Pacific, with others to follow. Based on the lessons learned from this study, we will develop more comprehensive digital game-based systems for elderly users as well as better applications of the games for healthcare practitioners such as nurses and therapists who use digital games for physical rehabilitation and exercise training for the elderly. Also, we will study further how digital game games can best be utilized to promote elderly Finns' physical health in both nursing and home-based settings.

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Serious games and active healthy ageing: a pilot usability testing of existing games

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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 mapping the existing games for seniors, conducting a pre-test on console games, interviewing elderly, and a literature review on the motivational factors for elderly. The findings showed us the limitations of the existing games and technologies. The literature review gave the useful game design opportunities. The insights from these pre-studies helped us to form the agenda, activities, and plan for our project. According to the proposed activities, we conducted a pilot testing of existing games with elderly and found out that the existing games have potential to be re-used with further modifications in our project. Furthermore, we learned the important lessons from this testing in terms of game design, interaction, and design opportunities. Then, we continue to re-design the existing games and develop new games followed by a usability testing.

Keywords: serious games; gamification; active ageing; usability testing.

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1 Introduction

Active ageing is the process of optimising opportunities for health, participation, and security in order to enhance quality of life as people age (*Active Ageing: A Policy Framework*, 2002). This term can be applied to both individuals and groups and it emphasises the ability to participate in society while being provided with protection, security, and care. Well-being in this matter is understood widely as physical, mental, and

social well-being (Peel et al., 2005). Nowadays, many everyday services such as banking, insurance, and healthcare are becoming digitalised. Thus, the digital divide and unequal opportunities of using modern technology can alienate seniors from society. The inclusion of seniors in the development of the information society is very important. One aspect of the information society is the increased gamification of various things such as learning or exercise. Gamification is the process of applying game-design thinking to traditionally non-game applications and functions to make them more fun and – above all – more engaging.

Serious games are games that are used for purposes other than mere entertainment. They can be used in several application areas, such as military, government, educational, corporate, and healthcare (Susi et al., 2007). Some research has been conducted on the positive effects of games and they have been found to affect, for instance, analytical and spatial skills, strategic skills and insights, learning and recollection capabilities, psychomotor skills, and visual selective attention (Mitchell et al., 2004). In healthcare, serious games have been used to enhance physical fitness, educate health/self-directed care, distraction therapy, recovery and rehabilitation, training and simulation, diagnosis and treatment of mental illness, cognitive functioning and control; for example see (Taylor et al., 2011; Adamo et al., 2010).

This paper describes the purpose and research activities of a project called gamified solutions in healthcare (GSH). Moreover, we report the findings from our pilot usability testing with the elderly participants. Then, we also mention our future work and the direction of the project. Basically, GSH project develops new services and effective activity solutions for elderly people through gamification. The purpose is to include elderly people in the development and testing of games that could be used for more than just entertainment purposes. Since this field is quite new, we conducted a pre-study in the beginning of the project in order to form our research agenda and the activities. The aim of this paper is to describe the results of the pre-studies of GSH project. Our purpose is three-fold: firstly, to map the existing games on the market that could be used as such or could function as an example of features that a game suitable for seniors could have. This search was limited to games that could enhance health and well-being (physical, mental, and social). Secondly, we evaluate the features in games that could make them senior-friendly or unfriendly. Thirdly, we examine what kind of barriers or attitudes there could be in the process of introducing games for the elderly.

This paper is structured as follows: we start with a literature review on serious games for healthcare followed by an introduction to the GSH project. The methods and results of a pre-study will be summarised and then, we report the activities in the research agenda of GSH project. We present and discuss the findings from the literature review on the motivational factors for elderly and the pilot usability testing of the existing games. Finally, we mention our future works of the project.

2 Literature review

Nowadays, the use of digital games for specific purposes has become increasingly popular in several areas (e.g., education, healthcare). Digital games are designed to make the players experience high levels of motivation and engagement in the gameplay (Watters et al., 2006). Video games have been known as a form of an engaging platform

for the players because of their entertaining, motivating, and fun activities. One of the main motivational factors in computer games is the sense of control that includes users' influence on the course of events and a tight relationship between users' actions and the outcome of the game (McCallum, 2012). According to Prensky (2001), digital games are potentially the most engaging pastime in history and it is due to the combination of game elements such as fun, play, problem solving, challenge, rules, and story-telling. Over the years, there is an increasing interest in digital games among professionals, researchers, and practitioners. For example, the concept of edutainment (education and entertainment) is widely accepted in learning. In business, people tend to use the concept of gamification in their business models and marketing strategies (e.g., Nike gamified their marketing strategies).

The use of digital games for healthcare is one of the promising areas. Recent studies showed that healthcare professionals are getting interested in using computer games for rehabilitation (Burke et al., 2010). Virtual rehabilitation can provide a natural or real-life environment; individuals have the opportunity to forget about their surroundings and situation and focus directly on a task in the simulated environment (Halton, 2008). Among commercially available games, Nintendo Wii seems to be one of the most promising technologies as a therapeutic tool in rehabilitation because of its low-cost hardware and physical-based interaction with the game. Wii encourages players to use natural actions to play games and has gained the support of occupational therapists because it is easy to use, entertaining and has a wide variety of games that can help patients perform therapeutic training (Anderson et al., 2010). The current needs of healthcare industries are low healthcare costs and affordable healthcare, better health outcomes and healthier population, and better patient experiences and patient engagement (IBM, 2014). To address these healthcare needs, serious games have potential.

Serious games have been proven in preventative care and behaviour modification (e.g., games for diabetes prevention and behaviour change for sufferers). Moreover, they have been used in long-term healthcare (e.g., rehabilitation) as well as chronic diseases (e.g., cancer). According to Anelea (2014), they have created a new game for smart-phone users that allows the players to analyse real cancer data with the intention to help scientists to find potential treatments. Exergaming is another interesting area and it has potential as a remedy to the growing societal healthcare problems (e.g., children's obesity and diabetes). Rizzo et al. (2011) reveal that game-based activities with functional body movements can have positive health outcomes for diabetes patients and obese children. Ruppert (2011) advocates that adopting virtual environments in the health context can make a significant difference in treating anxiety disorders, drug and alcohol abuse, eating disorders, impulsive disorders, and more.

For ageing population, digital games are used to improve the elderly's quality of life. Ijsselsteijn et al. (2007) reveal that the use of digital games to enhance the mental and physical activities of elderly (e.g., social connectedness and exercises) is promising. Nintendo Wii is used as a socialisation tool to promote the intergenerational relationship and communication between the young people and the elderly (Theng et al., 2012). Kahlbaugha et al. (2011) advocate that Wii can have positive impacts on the physical activity, loneliness, and mood of elderly. Pyae et al. (2013) reported that augmented reality-based rehabilitation system can have positive impacts on the motivational level of

elderly stroke patients. Tong and Mark (2013) mention that digital games can stimulate cognition and enjoyment, which often declines due to age-related changes. Whitlock et al. (2014) advocate that digital games are progressively used as a therapeutic tool in healthcare, context from improving cognitive abilities of the elderly to rehabilitation and pain management.

Despite having the potentiality, there are noticeable gaps and problems in using digital games for elderly and healthcare. Gerling and Masuch (2011) point out that not all commercial game are accessible to elderly. They conducted an exemplary focus group analysis of Wii Sports and Wii Fit games with the frail elderly players and a variety of usability issues were observed during the gameplay sessions (e.g., controller issues). Marinelli and Rogers (2014) advocate that most exergames available on the market do not support elderly-friendly design and gameplay. They evaluated two exergames for Microsoft Xbox 360 with the elderly players and the findings showed that the significant usability issues in these games may hinder the elderly's use of the games (e.g., cluttered interface). According to Webster and Celik (2014), they highlight on the limitations of current Kinect-based exercise games such as game designs for specific players, game customisation, lack of effective feedback, and lack of long-term study. Marin et al. (2011) reveal that the use of digital games for the elderly population requires an in-depth inspection to ensure optimum benefits on the elderly's healthcare outcomes. McLaughlin et al. (2012) point out that it is important for the designers to understand the capabilities, limitations, and interest of elderly to create successful game stories and mechanics.

In general, this literature review reveals that the area of gamification for elderly and healthcare has noticeable challenges that need to be overcome so that the researchers can investigate whether digital games are beneficial to elderly's well-being.

3 Gamified solutions in healthcare

GSH is a joint research project between Turku University of Applied Sciences and the University of Turku. In cooperation with Serious Games Finland Oy, Attendo Finland Oy, City of Turku Welfare Division, and Puuha Group Oy, the project researches and develops new gamified services. The project results are aimed for healthcare utilisation, physical exercise, social inclusiveness, and enhanced quality of life. The project is funded by Tekes (the Finnish Funding Agency for Innovation) until the end of 2015. A basis for this project is a study that was conducted together with Serious Games Finland, Sendai Finland Wellbeing Center, and Sendai National College of Technology. Serious Games Finland was interested in testing their serious game called Liitäjä in Japan (Nakai et al., 2013). At the same time, our researchers were cooperating with Puuha Group in their gamified playground project resulting in the first prototype that was presented in the Turku International Book Fair in October 2013 (see Figure 1). Since this prototype is a combination of mechanical engineering and game development it represents a quite unique approach and it opens for the GSH project new research questions to be studied. Moreover, the industrial partners Serious Games Finland and Puuha Group both have interests in the emerging Asian markets.

Figure 1 The gamified playground instrument presented in the Turku international book fair (see online version for colours)

4 Pre-study methods and results

The purpose of the pre-study was to get a basic understanding of the current stage of games and attitudes towards games among seniors in order to form a more detailed research agenda and the activities for the project. The aim of the pre-study was not to get scientific or generalisable information about the topic but rather to help us to formulate the research topics that should be answered during the project. The pre-study consisted of three stages:

Phase 1 Mapping senior-friendly games in the market.

Phase 2 Evaluating senior-friendly and unfriendly features in the games.

Phase 3 Getting a basic understanding of possible barriers and attitudes when introducing games to the elderly.

In Phase 1, we identified 30 games. Our inclusion criteria were that the game is suitable for senior users and it should improve health and well-being. These 30 identified games were then tested and classified into the following categories:

1 games for physical activity

2 games for social activity

3 games for mental activity.

Games for physical activity are mainly console games that used different sensors that recognise movements. Games for social activity are games that one could play with other people such as bingo, chess, and chats. Games for mental activity are games that activate the brain and memory such as memory games, and problem solving games.

In phase 2, we selected different games out of many commercial games that will be used for our future usability testing with the elderly participants. Basically, a team of 12 health informatics students tested different console games and identified the game actions that can improve physical activity. Problems that we observed and identified during the test were related to:

- physical limitations: the games included jumps, fast movements and other elements that were not considered senior-friendly
- visual elements: the games were full of visual, moving elements
- usability: the beginning of the games was complicated and took a lot of time, the instructions were in small print and with no language options
- focus: the focus in many games was more in body building and fitness exercise
- selection of sports: several games were about roller skating, street dancing and many other sports that are not that familiar or important to seniors.

In phase 3, we conducted three interviews of seniors, who were over 70 years old and were using a health technology service. The themes of the interview were games in general, willingness to play digital games for health and well-being and issues related to the use of information technology in general.

The interviews revealed several interesting issues about gaming among seniors. For instance, attitudes towards games in general may not be as positive as among younger generations. Games were considered to be something for people with nothing better to do. Also the word 'exercise' was considered something that young people or women would do. However, when discussing the topic in more detail, the seniors revealed several games that they have played and could play, for instance chess, coin slots, poker and quizzes. Games that the seniors would play together with others seemed to gain a more positive response than games that you play by yourself. The seniors were also concerned about their information technology skills and some thought they would not have the mental capabilities to learn digital games. Physical limitations were also seen as a problem.

In the pre-study, we identified some gaps in the current knowledge, which gave us in-depth understanding and insightful ideas that will help us in designing and developing gamified services for elderly in the project. Based on the findings from the pre-study, project plan, and discussions, it became imminent that we should conduct more research about the seniors' attitudes towards gaming and digital games. Especially, we need more focus group interviews as well as some usability testing with console games. This includes also attaining more knowledge about the physical limitations and their influence on gaming. Finally, the research requires systematic analysis about the existing games for seniors, and the attitudes and perceptions of health and social care workers that work with seniors. The research activities of GSH can be summarised in four primary topics:

1 gamification mechanisms
2 usability for elderly people
3 effectiveness of game solutions for elderly people (e.g., business and production models)
4 attitudes and acceptance of games by the elderly people.

5 Understanding motivational factors for elderly in rehabilitation

According to our proposed research activities, we conducted a literature review on the role of motivation in elderly's rehabilitation (Pyae et al., 2014). We specifically focused on the motivation of elderly in stroke rehabilitation and ideated how we can be mapping out these motivational factors on designing games for rehabilitation. We have found out that there are many social and environmental factors that can influence on the level of motivation of elderly in doing rehabilitative physical exercises.

Social functioning such as social contact, social activity, and social encouragement, is one of the most important factors that can have an impact on the patient's level of motivation. In designing games, we can apply the idea of socialisation for elderly into social-based games such as intergenerational game, multiplayer game, and social activity game. The relationship between therapist and patient plays a vital role in rehabilitation that can improve patient's motivation. When we design games, we can apply this idea in using virtual characters (e.g., friendly therapists) in the game. We found out that personal goals are important in rehabilitation. Having a personal goal in the rehabilitation process can make elderly more motivated and engaged in their physical exercises. Therefore, we can design goal-oriented games for elderly's physical training and rehabilitation. In addition, rehabilitative environment and setting are regarded as an important motivational factor for elderly. Hence, we can design elderly-friendly environment in the game context such as household environment, neighbourhood, and service homes for elderly.

Individual motoric level can be varied from one patient to another. Therefore, the customisation or personalisation is an essential part of the rehabilitative training. Thus, we can design customisable games for elderly so that they can meet their individual needs. There are other important motivational factors for elderly and their rehabilitative activities such as meaningful rehabilitative tasks, information from healthcare professional, positive feedback and encouragement from therapist, and recreational and leisure activities. All the motivational factors are useful and insightful for our future game design and development. Moreover, these findings may be helpful when we are designing gamified services such as socialisation, rehabilitation, entertainment, and counseling systems. The summary of our findings from literature review is listed as below (see Table 1).

Table 1 Motivational factors for stroke patients in rehabilitation

Motivational factor	*Indication to game design*	*References*
Social functioning	Multiplayer game Intergenerational game	Maclean et al. (2002), Krause et al. (2001), Shimoda and Robinson (1998), Sanntus et al. (1990), Evans et al. (1988), Domboyy et al. (1986) and Barry (1965)
Patient-therapist relationship	Virtual character such as therapist and nurse	Maclean et al. (2002) and Barry (1965)
Setting relevant rehabilitative goal	Goal-oriented game	*Finding Motivation after Stroke or Brain Damage* (2014)
Rehabilitative setting and environment	Household environment, Service homes for elderly, Public spaces (e.g., park)	Holmqvish and Koch (2001)

Table 1 Motivational factors for stroke patients in rehabilitation (continued)

Motivational factor	*Indication to game design*	*References*
Information from healthcare professionals	Game help system Game tutorial	White et al. (2012)
Meaningful rehabilitative task	Elderly friendly sport games Household chores	Flores et al. (2008)
Individual needs and customisation	Game personalisation and configuration	Flores et al. (2008)
Positive feedback from therapist	Game feedback and score	van Vliet and Wulf (2006)
Music for rehabilitation	Game background music, Audio feedback	Knight and Wiese (2011)
Recreational activities for stroke patients	Recreational games such as chess, bingo, and dance games	Roth and Wisser (2004)

6 A pilot usability testing

According to our proposed research activities, we conducted a pilot usability testing of existing games at the elderly service home in Rääkkylä in Finland. Before we conducted the pilot usability testing, we recruited five elderly participants who are the regular participants in the social activities and physical exercises programs arranged by the community centre. Their average age range is from 62 to 85 and their health conditions are sound and stable although some of them suffer from age-related health problems such as memory loss, hearing problem, and limited mobility. They are fairly active in their daily lives in terms of social activities and physical exercises (e.g., walking, cycling). For this user testing, we chose two commercial games and Puuha Group's SportWall game which is designed for physical activities of various age groups. Basically, SportWall game uses Xtreme reality technology and a traditional webcam to detect the player's movement. This gameplay is designed for roller skating exercise and the player needs to use particular body postures and gestures to control the game.

Concerning commercial games, there are many sport activity games on the market. Among them, we selected Microsoft Xbox's Kinect-based climbing game and PlayStation3's PlayMove Controller-based tennis game. The reason why we chose these two games over others is that Kinect-based games are promising to be used as a tool to improve the patient's experiences in rehabilitation. Moreover, Xbox supports a variety of sport games that may be used as game-based physical exercises for elderly. For PlayStation3's PlayMove tennis game, it also supports a variety of sport games (e.g., bowling, tennis). Moreover, PlayStation3's PlayMove controller is interesting to be tested with elderly whether it is elderly-friendly and useful for them. After discussing with the caregiver at the service home, we chose only three games to be used in our study because of the physical and mental tolerance of the elderly participants. The main objectives of this pilot study are as follows:

1 to investigate the usability and usefulness of commercial games and SportWall game for the elderly

2 to find out the usability and usefulness of multimodal input devices for elderly (Kinect for Xbox One, PlayStation3's PlayMove controller, and SportWall's traditional webcam and Xtreme reality technology)

3 to understand the general user experiences of elderly in gameplay.

7 Pilot usability testing design and procedure

Firstly, we prepared the game stations at the elderly service home before we conducted the testing. We set up the games: Xbox game console, PlayStation3 game console, Microsoft's Kinect for Xbox One, PlayStation3's PlayMove controller, SportWall game with traditional web cam, and two large-screen TVs. To be able to investigate the elderly participants' problems, difficulties, and responses during the game sessions, we recorded their actions and gameplay by using two video recorders from both front and back views. For the questionnaire session, we used a voice recorder to capture the conversation between the research and the elderly participant for future reference.

Before we started the game sessions, we asked every participant's consent to involve in the study. Then, we performed a quick introduction session to our usability testing, digital games, and the objectives of our study. There were three game sessions in this study. In session one, the elderly participants played Xbox's Kinect-based climbing game followed by a quick questionnaire session to investigate their responses and feedback towards the usability and usefulness of the game and the Kinect. In session two and three, the elderly participants played PlayStation3's tennis game with PlayMove controller and SportWall game with webcam respectively. For every game session, the researcher guided the elderly participants how to play the game by going through a quick game tutorial. To avoid learning effects in playing games, we randomly assigned the elderly participants to play the particular game. In the entire usability testing, the administrator at the elderly service home monitored every participant to protect them from being fallen and exhausted while they were playing the games.

After finishing all sessions, the researcher asked the general interview questions to the elderly participants about their overall experiences. Due to the limited time and tolerance of the elderly participants, we used short and simplified version of usability questionnaire to collect their feedback. Table 2 shows the detailed procedures of our usability testing. According to the estimated time taken for individual elderly participant, each game session took 15 minutes including game tutorial, gameplay, and questionnaire session. However, individual session was varied from one participant to another. As each participant had to play three games in the whole usability testing, it took about 60 minutes individually. The whole usability testing with five participants took about 3 hours.

Table 2 Usability testing design and procedures

Tasks	*Description*	*Time taken*
Introduction to usability testing and getting consent	Researcher explains about usability testing procedures and asks consent from every participant.	10 mins
Gameplay session 1	Quick tutorial of game	5 mins
	Participant plays Game 1 (Xbox climbing game)	5 mins
	Questionnaire	5 mins
Gameplay session 2	Quick tutorial of game	5 mins
	Participant plays Game 2 (PlayStation's PlayMove tennis game)	5 mins
	Questionnaire	5 mins
Gameplay session 3	Quick tutorial of game	5 mins
	Participant plays Game 3 (SportWall game)	5 mins
	Questionnaire	5 mins
Post gameplay interview	Researcher asks post gameplay interview questions to the participant.	5 mins
	Total time taken	60 mins

Figure 2 A pilot usability testing (see online version for colours)

In this study, we used a set of questions to investigate the elderly's personal information, health condition, user experiences, and feedback. The general interview session before gameplay includes questions such as age, gender, health status, physical activities, and prior experiences in playing digital games. The usability questions include usefulness, simplicity, and ease of use of the games and interactive input devices. Besides, we asked their experiences in gameplay in each game session such as how quick they can learn to use a particular device and how well they can perform by using this device. We also asked if they had fun to play the game and if each game was challenging enough to play.

After that, we asked the general interview questions to the elderly participants such as their problems and challenges encountered in each game session. All questionnaires, except general interview questions, were based on FIVE-points-scale from strongly disagree (1) to strongly agree (5). The researcher and the caregiver helped every participant to be able to answer the questions. Figure 2 shows that one of the participants was playing during the usability game session.

8 Findings

Generally, the elderly participants in our study are moderately active in their daily lives and physical activities. They all participated in every game session and they gave their feedback on the games and their user experiences. According to the general interview session before they played the game, they all did not have prior experiences in playing digital games and they had a few difficulties in answering questionnaire. Therefore, the caregiver at the centre and one of our researchers guided them in both questionnaire and gameplay session.

In session one, the elderly participants had some problems while they were playing the game (Xbox's climbing game) by using Kinect sensor because it was their first time playing digital game. However, after the researcher had guided them how to play the game and they have gone through the tutorial session, they could continue playing the game without major challenges. In this session, we found out that the graphics, the user interface, music, and audio feedback in the game were cluttered and not elderly-friendly. Therefore, sometimes they were distracted in gameplay and could not continue to play the game. Kinect-based interaction seemed to be effective for the elderly in gameplay.

In session two, we found out the major challenge experienced by all elderly participants. For PlayStation3's tennis game, they used PlayMove controller to interact with the game. Basically, it is necessary to press the buttons of the controller to play the tennis game. For the elderly participants, it was found out that they could not handle the controller properly and they forgot to press the buttons most of the time. As a result, they could not proceed with the game after some time. Although they liked the idea of tennis game, all of them did not achieve the game to a certain level in this game.

In session three, it was generally found out that all participants could perform well in SportWall game. The gameplay was simple and the game interface was clean and uncluttered. As the game used the traditional webcam, the interaction with the game for the elderly was not challenging. The elderly participants used different body postures and gestures to control the game. Noticeably, we found out that some game actions (e.g., jump, sit) were not safe for the elderly because it could make them fall and they may be exhausted after some time.

According to the elderly's feedback, we found out that Kinect for Xbox One was the most effective input device for the elderly participants (mean score 3.36) whereas PS3's PlayMove controller seems to be the hardest for the elderly participants (mean score 2.64). The SportWall's webcam-based interaction was the second most effective device for the player (mean score 3.28). However, the average scores of these two devices (Kinect and SportWall's webcam) were not noticeably different. Table 3 shows the summary of average usability score that each input device has achieved.

Table 3 Usability of interactive input devices

Input device	*Usability*	
Kinect for Xbox one	It is useful in gameplay.	3
	It is easy to use.	3.2
	It is simple to use.	4
	I learned quickly to use.	3.2
	I performed well.	3.4
	Mean score	3.36
PS3's PlayMove	It is useful in gameplay.	2.6
	It is easy to use.	2.6
	It is simple to use.	3
	I learned quickly to use.	2.4
	I performed well	2.6
	Mean score	2.64
SportWall's webcam	It is useful in gameplay.	3
	It is easy to use.	3.2
	It is simple to use.	3.4
	I learned quickly to use.	3.4
	I performed well.	3.4
	Mean score	3.28

Regarding their feedback towards the usability of each game, the elderly participants enjoyed the most to play SportWall game followed by the Xbox's climbing game. However, they were not noticeably different from each other in term of the mean score they have achieved (mean score 3.42 for Xbox and 3.46 for SportWall). In contrast, PS3's tennis drew the least attention from all elderly participants and they did not enjoy the gameplay (mean score 3.3). It seems that the difficulties to use the controller in playing game could influence on their overall user experiences.

In general interview session, 4 out of 5 elderly participants answered the questions whereas the participant (S3) did not comment on the games. The elderly participants mentioned their interests in all games. The participant one (S1) mentioned that it was enjoyable to play the games. However, he was not strongly confident to play it again by himself. Moreover, he advised that either therapist or caregiver should guide him how to play the game because he mentioned that he could easily forget it. With regard to the interactive input devices, he pointed out that PlayStation3' PlayMove was difficult to use and to interact with the game. The other participants (S2, S4, and S5) gave the general positive feedback on the games and controllers and they all would like to play the games at the community centre or home.

In addition to the feedback from the elderly participants, we managed to interview the caregiver at the centre regarding the usability and usefulness of the games and the interactive devices. She generally thought that game-based physical activities are interesting and it is promising to improve the elderly's motivation in doing physical exercises and also it can enhance the socialisation of elderly if they perform in group activities. Besides, she advised that the games should be simple and easy enough for the

elderly because of their limited mobility and weak memory. She also mentioned that majority of elderly residing at the service homes are not familiar with digital games. Thus, it would be useful if the games are elderly-centred. She also suggested that controller-free motion-based games are easy and simple enough for the elderly players. She requested that she would like to install some digital games at the centre and test it out with elderly for long-term.

9 Discussion

We pinpoint the important findings from this pilot usability testing. The commercial games that we used in this study are not elderly-friendly due to the cluttered user interface, distracting graphics, and audio feedback. Sport activity-based games could draw the attention from the elderly participants. However, the gameplay should be simple but challenging enough for the elderly player. SportWall game seems to be the most effective game in terms of its user interface, gameplay, and instruction because it is simple, clean, and easy to play. However, it is noticeable that we should avoid the game actions or body posture that can trigger the possibility of elderly's fall during their gameplay. Besides, when we design the games for elderly, we should consider avoiding the extreme game actions that can easily lead to the exhaustion of the elderly player. For example, jump action in the game is unsafe for the elderly.

With regard to the interactive input devices, we found out that controller-free motion-based input devices seem to be rather effective and efficient for the elderly players. In contrast, complicated functions of the controller can make the elderly confused and distracted in playing games. Concerning the motion-based input devices, the synchronisation, responsiveness, and accuracy of a particular sensor are important for better user experiences. Although the elderly participants would like to play the games again, most of them still lack the confidence in playing the games by themselves. Therefore, it is important for us to take into consideration how we can improve their level of confidence in terms of game design and gameplay. Based on the findings from this pilot study, we can outline our future tasks as below:

1 to re-design the Puuha Group games to be suitable for elderly player

2 to further develop, enhance, and run the pilot test of Puuha group games to investigate whether these games are elderly-friendly

3 to run the pilot usability testing of other existing games in our project

4 To conduct the usability testing of new games with a large number of elderly in the service homes in Finland and in Asia.

In this pilot study, we have a number of limitations. Firstly, the number of elderly participants is quite small. Secondly, we have tested only two commercial games out of many other games because of limited time and physical tolerance of the elderly participants. Thirdly, we have conducted the study for only one day and the elderly participants have played only three game sessions in the entire user testing. Lastly, we have used short and simple questions in the interview session and it did not cover all parts usability questionnaire.

10 Conclusions

We have conducted a pre-study of existing games, forming a research agenda and activities, a literature review on motivational factors for elderly, and a pilot usability testing. The findings from these studies are insightful for our future game development. By conducting these pre-studies, we had a clear vision on our future research direction. In the first pre-study, we have selected the suitable commercial games for our future user testing. We have also investigated the elderly's general attitude towards digital games for physical activities. Based on the findings from this study, we have found out the limitations of existing games in terms of interface, gameplay, visual and audio feedback, interaction, and genre. These findings helped us to emphasise on the particular games that are promising to be used for future testing. The literature review on the motivational factors for elderly provided us game designs opportunities that can be mapping out on the existing games and future development.

According to the research activities of GSH, we have conducted a usability testing with five elderly participants and we have learnt the important lessons from this usability study. By conducting this testing, we have learned to avoid the unsuitable game interfaces, features, game context, and movements that are not friendly for the elderly whereas insightful game design principles that we have learned from this study can be applied in our future game development and improvement. Moreover, we have found out that some existing commercial games and technologies (e.g., Kinect sensor, Xbox Sport games, SportWall game and Xtreme reality technology) can be modified and used for our future games.

In the future, we will test our existing games with modifications and new games with large elderly sample size so that we can investigate the new insightful findings for our project and games. Besides, we aim at testing these games in the different cultural context and regions (e.g., Asia) to understand how they can be adaptable and customisable for different user groups.

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Rehabilitative Games for Stroke Patients

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Abstract

Stroke is one of the major problems in medical and healthcare that can cause severe disability and death of patients especially for older population. Rehabilitation plays an important role in stroke therapy. However, most of the rehabilitative exercises are monotonous and tiring for the patients. For a particular time, they can easily get bored in doing these exercises. The role of patient's motivation in rehabilitation is vital. Motivation and rehabilitative outcomes are strongly related. Digital games promise to help stroke patients to feel motivated and more engaged in rehabilitative training through motivational gameplay. Most of the commercial games available in the market are not well-designed for stroke patients and their motivational needs in rehabilitation. This study aims at understanding the motivational requirements of stroke patients in doing rehabilitative exercises and living in a post-stroke life. Based on the findings from the literature review, we report factors that can influence the stroke patients' level of motivation such as social functioning, patient-therapist relationship, goal-setting, and music. These findings are insightful and useful for ideating and designing interactive motivation-driven games for stroke patients. The motivational factors of stroke patients in rehabilitation may help the game designers to design motivation-driven game contexts, contents, and gameplay. Moreover, these findings may also help healthcare professionals who concern stroke patient's motivation in rehabilitative context. In this paper, we reported our Virtual Nursing Home (VNH) concept and the games that we are currently developing and re-designing. Based on this literature review, we will present and test out the ideas how we can integrate these motivational factors in our future game design, development, and enhancement.

Keywords: rehabilitation, motivation, digital games, human-computer interaction, user requirements.

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1. Introduction

Stroke is one of the major medical and healthcare problems that can cause severe disability, partial paralysis, memory loss, and even death of sufferers. According to Burke et al. [1], 85% of patients live with impaired upper and lower limbs after suffering from stroke. The World Health Organization (WHO) states that every year there are 15 million people who suffer from stroke in the world. Among them, 5 million patients die and another 5 million are living with permanent disability that negatively impacts their quality of life. Stroke survivors may experience limitations in range of motions, fine motor skills, gross motor skills, reaching, and manipulation. These deficits can dramatically change the patient's daily life that has to be dependent on others (e.g., family members or caregivers) in doing personal management such as showering, feeding, changing clothes, house chores, and ADL (Activities of Daily Living) tasks. Because of these physical limitations after stroke can reduce patient's participation in social and leisure activities, community programs, and work activities [2]. As a result, it may lead to depression, social isolation, and loneliness in life. Rehabilitation training, in which repetitive exercises are involved, can help the stroke patients with motor impairments of lower and upper limbs to overcome the physical limitations following stroke [2]. Rehabilitation is the essential part of

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the stroke recovery for stroke survivors because repetitive and rehabilitative exercises can support the brain to get sufficient stimuli to remodel and to regain better motor control. Moreover, rehabilitation can help the patients retrain their functional abilities in walking, transferring, balancing, and doing ADLs.

However, stroke therapy involves daily rehabilitative exercises, which include repetitive movements of the affected limbs. Patients typically complain that these exercises are monotonous, tiring, and boring. Chang et al. [2] pointed out that only 31% of patients who have post-stroke motor deficiencies perform the therapeutic exercises as prescribed by the physiotherapists. Early termination of stroke rehabilitation may lead to permanent disability in life. Motivation and therapeutic outcomes are strongly linked [3]. Healthcare professionals generally believe that patient's motivation plays an important role and it can largely determine therapeutic outcomes. There are other factors that can negatively impact on the patient's motivation in rehabilitative process such as lack of social support from family members and friends, expensive fees of stroke therapy, difficulty in travelling to rehabilitative center, and lack of caregiver who can look after them.

2. Background

Recent studies show that healthcare professionals are more and more interested in using computer games for stroke rehabilitation [1]. In general, video games are known to be an engaging platform for the players and gamers because of entertaining, motivating, and fun activities. Virtual rehabilitation has received a great interest from many researchers and healthcare professionals because it can provide a real world environment (e.g., tennis court in sport game or ski resort in leisure game) where players can forget about their surroundings and situation and pay attention to a task in a simulated virtual environment [5]. By playing digital game-based rehabilitative exercises, stroke patients may have improvements in the upper and lower limb mobility as well as higher level of motivation and fun. Among the commercial games available in the market, Nintendo Wii seems to be the most promising technology to be used as a therapeutic tool in stroke rehabilitation. Because of its low-cost hardware and physical game activities, many researchers have tried to use Wii games in stroke therapy. Basically, Wii encourages game players to use physical movements and natural actions in gameplay (e.g., playing tennis in Wii Sports). It has gained positive feedback and support from the therapists because of its ease of use, entertaining game contents, and a wide variety of games available which can help patients to perform therapeutic training and physical exercises [6]. Although Nintendo Wii is useful and usable in rehabilitation, there are some usability issues that can be critical to the patients who play the games for rehabilitative purpose. For instance, the players cannot customize the level of difficulties in the game itself to meet the needs of different levels of disability. Besides, it does not convey therapeutic feedback to the patients and it does not monitor the patient's progress in every session. The other game consoles available in the market such as Microsoft Xbox, Sony PlayStation, and Eye Toy are also not designed for rehabilitation and therapeutic training because these games are only targeted for young and healthy users. Furthermore, these games are mainly for fun, entertainment, and recreation. The game content in these game systems is not targeted for stroke patients. Thus, physical movements in the gameplay are difficult and not suitable for stroke patients. As these games are solely aimed for healthy players, the motivational content of the games is also not suitable for the motivational needs of the stroke patients. Therefore, all these gaps between rehabilitative and motivational needs of stroke patients and existing gaming technologies should be bridged. In this study, we aim at understanding and having empathy on the needs of the stroke patients' motivation in rehabilitation for designing rehabilitative games for them.

3. Motivational Factors

To design and develop interactive motivation-driven games for stroke rehabilitation, it is important to understand and to have empathy for the problems, needs, motivation, pain points, and goals of stroke patients. In this study, we conducted a literature review to explore and to understand the motivational factors that can influence stroke patients in rehabilitation. According to the literature, there are many factors that can have an impact on the stroke patients' motivation in doing rehabilitative exercises and living post-stroke life positively. Social and emotional support from family members, patient-therapist relationship, role changes in family, understanding in rehabilitative process, long and short term goals, and music are some of the important motivational elements that can affect the patient's level of motivation in performing and continuing their rehabilitation that can lead to faster recovery from the stroke. Motivation has been variously described in terms of innate and internal drives or needs, inner stimuli and responses, and goals or the directions of the motivation. The motivation concerns the intrinsic and extrinsic conditions responsible for variations in the intensity, quality, and direction of on-going behaviour [7]. To understand a patient's motivation, one must also consider the environmental pressures that can impact on the patient and include the demands of his or her condition after stroke. In fact, there are environmental factors associated with most of the patients' needs or drives. Research on the stroke patients' motivation is necessary to focus either on the inner needs of the patients, or on the environmental pressures and demands.

3.1. Social Functioning

Social functioning such as social support, social contact, and social integration, plays in an important role for the post-stroke patients. Social contact and social support may not only improve the physical recovery of the patients but also enhance the level of motivation in rehabilitation. Moreover, it may encourage the stroke patients to actively engage in the rehabilitative training. Patients who receive social support from family members are likely to get higher motivation in rehabilitation. In contrast, socially isolated patients are likely to have less motivation in rehabilitation and they are pessimistic about the post-stroke life. Dombovy et al. [8] state that stroke rehabilitation is the combination and coordination of social, medical, educational, and vocational measures for training a patient to regain the highest level of functional recovery and ability. They continue to say that encouraging the socialization of a stroke patient is one of the factors of well-established principles of rehabilitation for stroke. Santus et al. [9] point out that the family is a natural source of social support for a stroke patient and it may influence his or her functional recovery by providing companionship and an opportunity for a normal life. They highlight that the rehabilitation program should emphasize not only the training for physical improvement but also education of family members and society how to support the patient socially and physically. Deteriorating relationships after the stroke are common phenomena for the stroke patients and social communication remains the most stressful issue. Changes in social activities, vocational interests, and role assignments also affect the family system of a stroke patient. Barry [16] points out that stroke patient's expectations on one hand and his or her significant others' expectations on the other hand can strongly influence on his or her level of motivation. The people who play a key role in the stroke patient's rehabilitation are not only the therapists but also his or her family members, friends, associates in whatever situation or setting he or she may live and work.

Evans et al. [11] advocate that social support and functional rehabilitative outcome after stroke are positively linked, suggesting that the support and involvement of family members in rehabilitation are important to speed up the recovery from the stroke. Although family encouragement was one of the factors that can positively affect the stroke patient's motivation, pushing too hard to make improvements in rehabilitation can lead to lower level of patient's motivation in therapeutic training [3]. In addition to this, overprotection can reduce the patient's level of motivation. Social connection with family members and friends is an important factor for patients after stroke but it is very challenging for them to communicate with other people such as understanding what people say, expressing their emotions, talking to other people, walking, eating out, and shopping. It can make the stroke patients feel depressed, discouraged, disconnected, and isolated at a time when they need more social support from family members, friends, and relatives [10]. It is true to say that everyone needs social support and stroke patients cannot be excluded from their social needs. There are many ways that family members and friends can socially support the stroke patients such as companionship from family members, peer's support in rehabilitation, sharing information about stroke rehabilitation and recovery, trying new things for them, listening to their concerns and frustration, sharing their stories, keeping connection with old friends, helping in social outing, participating in social events and activities, and making new friends. Shimoda and Robinson [12] state that a lack of social support can prevent the stroke patients from regularly attending rehabilitative training or lead to a lack of motivation in doing rehabilitative exercises. Most stroke patients can get their motivation through interaction with their beloved ones such as playing with their grandchildren (e.g., intergenerational games), eating out with partners, going cinema with their friends, and socializing with neighbors [13]. Krause et al. [17] states that in general, social support covers the terms such as affective support, information support, and tangible support [17].

3.2. Patient-Therapist Relationship

One of the most important motivating factors is the use of the therapist's relationship with the patient as a form of bringing about the patient's recovery, readjustment, and rehabilitation after stroke [16]. The relationship between the stroke patient and the therapist forms one of the motivational elements in rehabilitation. Maclean et al. [3] mention that if a therapist has low expectations of how a patient will perform in rehabilitative tasks, it may cause a negative effect on the patient's motivation. Positive feedback, support, and encouragement from the therapist are important for the stroke patients to gain confidence and positive emotions in rehabilitation. The therapists can encourage stroke patients to feel more confident and motivated to continue to do rehabilitative exercises in the process of stroke recovery whereas giving confusing messages to the patients about the role of therapists in rehabilitation could lead to unnecessary misunderstanding in therapy and it may negatively impact on the patient's motivation in continuing rehabilitation process. The therapist can increase the motivation of stroke patients by striking up a rapport with patients and discussing about their lives before and after stroke [3]. Generally, the therapists not only help the patients improve in physical rehabilitation but they can also consult the patient's social and family issues. Therefore, the relationship between therapists and stroke patients are crucial in stroke rehabilitation.

3.3. Setting Relevant Rehabilitative Goal

Post-stroke rehabilitation is described as a long-term process where the patient and the healthcare team try to get an agreement on the activities to be focused and the

goals to be achieved through interaction, negotiation, and collaboration between the stroke patient and the healthcare professionals such as doctors, therapists, and caregivers. Setting a relevant rehabilitative goal can positively impact on the stroke patient's motivation. However, the goals should be meaningful, realistic, achievable, and measurable. The smaller goals for stroke patients should be related to real-life goals which are meaningful, achievable, and realistic. Moreover, the personalized rehabilitation goals may enhance the level of motivation of stroke patients in rehabilitation. These personalized goals may vary from patient to patient. For example, a particular stroke patient may want to re-enter into the working life or to drive a car when he or she recovers from the stroke whereas another stroke patient may want to be more independent in doing ADLs. Therefore, a goal that can link to individual needs and wants may positively impact on the stroke patient's motivation and engagement in rehabilitation. Therapists and caregivers need to help the stroke patients to achieve the smaller goals of therapy such as better movements of limbs followed by the bigger goals such as re-integrating into community and going back to work [13].

3.4. Rehabilitative Setting and Environment

Rehabilitative environment is regarded as one of the important factors for patients' motivation in rehabilitation. Generally, it involves well-designed and patient-friendly rehabilitation room, communal meals, and group training sessions where the stroke patients can share their experiences about rehabilitation and learn each other's progress in training, are the positive factors of motivation that fasten recovery from stroke. Almost every stroke patient has to go through a rehabilitation process after they have gone through an acute hospital. They have to spend most of their time at a rehabilitation centre before they regain the functional abilities of the impaired limbs. Therefore, the role of the rehabilitative environment such as a rehabilitation training room, a setting of the gymnasium, and people in this environment, is important for the stroke patients to feel comfortable, convenient, and secure. In addition to personal factors such as health history and condition, gender, role changes in family, sex, social background, and educational background, individual patient's motivation may be impacted also by environmental influences that involve physical condition, social and emotional condition, and individual attitudes for rehabilitation [18].

3.5. Information from Healthcare Professionals

Highly motivated patients feel that education and information provided by the healthcare professionals can change their thinking about therapy. They may see it as not only a helpful solution but also the necessity of an important role in stroke rehabilitation [14]. Before a particular patient starts his or her rehabilitation program, it is important for the therapists to explain the information about rehabilitation and therapeutic exercises. In this way, the patients can understand the process of rehabilitation and the benefits of the exercises. Moreover, understanding the process of rehabilitation and its benefits can enhance the patients' level of motivation and engagement in rehabilitation. The information of rehabilitation process from the therapists and their explanation are important for the stroke patients to understand their condition, process, and progress very well, and which may lead to a higher motivation in rehabilitation and faster recovery from stroke.

3.6. Meaningful Rehabilitative Task

Occupational therapy (OT) includes relearning skills for doing activities of daily living for the patients to get independence in their daily lives. For example, personal grooming, showering, toileting, meal preparation, and money management are some of the ADL tasks in occupational therapy. These OT exercises are meaningful and they reflect the social lifestyles of the stroke patients. By doing activity based exercises (e.g., ADL-based rehabilitative exercises), the patients may feel motivated and more engaged in the exercises. Flores et al. [15] advocate that meaningful tasks should be integrated into the rehabilitation. By doing meaningful rehabilitative tasks, patients can get a direct relationship between the use of impaired limbs in the therapeutic training and the use in their activities of daily living.

3.7. Individual Needs and Customization

As motoric impairment can be different from one patient to another, successful rehabilitative program requires personalization or customization for the individual patients to address their problems, to meet their needs, and to adapt individual's motoric level. Adaptability is one of the important factors for individual patients so that the difficulty level can be increased when the patient's motoric abilities improve in a particular period [15]. Understanding individual stroke patient's needs, focusing on personalized or customized motivation, looking beyond simple fun elements to provide engaging and correct upper or lower limb movements and activities are the difficult challenges in stroke rehabilitation.

3.8. Positive Feedback from Therapist

The encouragement from medical professionals such as doctors, therapists, and nurses, plays a vital role in stroke rehabilitation. Often, the therapists have to not only explain the information about rehabilitation but support them with positive feedback so that the patients can feel more confident, motivated, and engaged in what they are

doing. The feedback from the therapist to the patients should be positive to encourage them to actively engage in the rehabilitation. It may help them feel more motivated in performing the rehabilitative tasks and encourage them to be more engaged, active, and confident. Feedback plays an important role in rehabilitative training to maintain and sustain the motivation of individual patient during the rehabilitation process. Extrinsic feedback or external response can encourage the persistence to perform better in a situation of physical education [19].

3.9. Music for Rehabilitation

Everyday many people expose music for different reasons such as relaxation, interest, and motivation. Generally, people use music to achieve different types of goals in everyday life such as to motivate in doing exercises, to get relaxation, to pass time when driving for long hours or taking bus for long distance. Music is an interesting area for the healthcare professionals and researchers to study on how it may affect the stroke patient's motivation in therapeutic way. Music therapy may be effective in reducing negative emotions such as anger, depression, and anxiety, whereas promoting positive affections such as happiness, joy, and pleasant. Music Therapy can be used as listening therapy for the stroke patients to listen to a list of songs that caregiver or music therapist has selected for them to match a mood or to bring back memories [13]. Music can trigger the positive emotions of the stroke patients that may lead to more engagement in doing rehabilitative exercises. Music can be used as a healing tool in the social and personal context that can have a positive impact on the emotion of individual patient who is recovering from a stroke. Moreover, it can enable social interaction between the therapist and the patient or among a group of people in a rehabilitative training session [20]. Music may affect the physical, mental, and social components of the post-stroke rehabilitation process in many ways such as therapeutic listening and rhythmic movements.

3.10. Recreational Activities for Stroke Patients

Recreational activities such as playing digital games or board games, singing songs, participating in social outings, and going out for shopping, are recognized as motivational elements for the stroke patients that enable better social connection and re-integration with peers, friends, therapists, and communities. By participating in recreational activities, the stroke patients may regain a sense of social reintegration and better social ties with other people. Moreover, it may overcome the issues of social isolation and depression and it may help the stroke patients to feel more motivated in rehabilitation training and improve their quality of life. There are many benefits of leisure activities that can positively affect individual well-being and quality of life. Recreational activities also help the stroke patients to enhance their physical and mental health condition, together with personal growth and social communication. Leisure activities are suitable for everyone who can experience positive moments from doing these activities regardless of what state of health he or she is in. While the types of the recreational activities a person has done before the stroke might be different from the leisure activities that he or she is currently doing in post-stroke life, the feeling of wellbeing that one gets from these recreational activities will not be different [21].

4. Game Design Principles

Understanding the stroke patient's motivation in doing rehabilitative exercises is an important step in designing digital games for stroke patients and rehabilitation. Thus, the findings from understanding motivational elements of stroke patients in rehabilitation can be applied as design inputs and considerations in the game design process. According to the literature review, social functioning such as social ties with friends, peers, and family members and social communication, is one of the most important motivational factors for the stroke patients to get motivated in doing the rehabilitative exercises which is why it is one of the most important design inputs for designing a game for stroke rehabilitation. In designing a digital game for rehabilitative purpose, we can design multiplayer game where two or more players can play the game together so that they can socially connect with each other through the gameplay. By playing multiplayer games, the stroke patients can build up the social ties with peers and have a mutual understanding between patients in a similar situation. Moreover, not only the patients but also the therapists or other healthcare professionals can monitor or even participate in the multiplayer game. To achieve the idea of improving socialization of the stroke patients, we can also design intergenerational games for them to maintain the social connection between the patients and their family members. According to Llyod [24], intergenerational communication between older adults and younger generation can decrease the prevalence of ageing and it can considerably support to improve the mental health and physical well-being amongst the elderly group. With regard to the digital game-based socialization, Theng et al. [25] insist that generally computer-mediated games can provide inter-generational gameplay (e.g., Multiplayer Sport Games). Moreover, it can support entertaining and socializing features that are used as tools to promote positive mental health, social health, and physical well-being of the older adults. To design digital games for stroke patient's rehabilitation, the concept of "Patient-Therapist relationship" can be used as a basis for the relationship

between virtual therapist and the player. Virtual therapist can be a narrator or a virtual coach in the rehabilitative training in the game itself. In addition to this, the customization of the avatar's identity selected by the player can be integrated in the game so that the player may have stronger connection to the virtual therapist in the game. According to Kenny et al. [26], Virtual Human Agent technology has been used by the researchers to develop 2D or 3D characters that are used in virtual reality games and applications. For example, these virtual characters can be designed as virtual therapists, virtual nurses, and caregivers in the context of stroke rehabilitation.

With regard to the setting a relevant and achievable goal in the rehabilitation, we can account this as a goal-based game for the stroke patients. It is important that the goals are realistic and achievable and meet the individual's needs. In designing a goal-based game, we can allow the player to set a particular goal to achieve at particular levels or to get certain ranks or to earn certain points or scores in the game. In this way, the player can feel more motivated and engaged in the gameplay. Well-maintained and clean rooms, friendly social interaction, and stroke patient friendly facilities are amongst the important settings in the rehabilitative context that can have an impact on the level of motivation. For the game design, game environment or context should be more realistic and familiar to the players and should reflect their social lifestyle. By designing a game environment reflecting the stroke patients' social lifestyle, it can help them to feel more engaged in the game itself, which can improve the level of their motivation. For example, we can design a virtual shopping game environment in which the players can do shopping activities that they used to do before the stroke. Pyae et al. [27] advocate that in designing game for stroke patients, game environment should be meaningful and it should reflect the player's social background.

Information provided by the healthcare professionals such as doctors, therapists, and nurses, is important for the stroke patient in stroke rehabilitation. In the game design, we can use this concept as a help system; for example, virtual training by a virtual therapist, and information provided by a virtual nurse or caregiver on how to conduct the game. In addition, a virtual character (e.g., virtual therapist) can provide the progress of the gameplay, game scores, and game incentives in real-time during the gameplay. Physical therapy focuses on regaining strength and mobility of the upper or lower limbs by doing therapeutic exercises whereas occupational therapy focuses on relearning real activities (e.g., ADL, community reintegration, personal management and cognitive skills) that a patient has lost after suffering from the stroke. These ADL-based tasks are basically meaningful and realistic to the patients. In a game environment, we can also include real world tasks in the game activities. For example, we can design a cooking game for the stroke patients where they can prepare and cook the meal and at the same time, they perform therapeutic movements followed by cognitive skills such as choosing the right ingredients for the food and manage the cooking time. Furthermore, we can design a game that based on real-world activities such as simulation for driving a car, virtual shopping tasks, use of mobile phone or ATM or public phone, purchase of a public transport ticket, and other social activities. According to Pyae et al. [27], by playing meaningful game tasks, the stroke patients may feel more engaged, motivated, and active in the rehabilitative training.

In stroke rehabilitation, the individual needs may vary from patient to patient. Thus, the therapists and nurses have to customize the rehabilitation based on the individual requirements and goals. As a game design consideration, it is important to implement the player's personalization and customization in the game itself such as user profile, game levels, game scores, and ranks. When designing games for stroke patients, we can customize the game-based therapeutic activities or tasks to reflect the individual needs and resistances such as strength, mobility, and endurance of upper limbs. User profile, avatar customization, and game level setup (e.g., easy, hard, and master) can be included in the game design which allows the therapists or the patients to customize the games to meet their individual needs. By achieving certain levels the players may feel more engaged and motivated in the gameplay. Real-time game feedback is considered as one of the most important elements in general game design. In stroke rehabilitation, positive feedback from therapists in rehabilitative training should encourage the stroke patients. In the game design, it should emphasize giving positive and encouraging feedback such as progression level, positive feedback in audio or visual display by the game itself, and certain scores as incentives for the players in whatever situation they are. By getting encouraging feedback or incentives from the game, the players may actively involve in the gameplay and it is bound to increase their level of motivation. Music therapy is helpful for stroke survivors not only for entertaining but also for therapeutic purpose. Since music can be used as an emotionally stimulating tool, music therapy can also help to enhance or maintain one's mental health and physical well-being, communication, social well-being, and quality of life [23]. The role of music is vital in designing digital games. The background music and audio feedback form important game elements to judge if a particular game is interactive, engaging, and enjoyable. When designing and developing interactive games for stroke patients, it is important to choose the right genre of music and audio feedback so that the patients feel more engaged and active in the gameplay. Finally, recreational activities (e.g., chess games, singing games, shopping games, card games, and puzzle) can be integrated into the game design to improve the stroke patient's motivation in the gameplay.

Table 1. Indication to the game design principles

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

After considering all the motivational factors that can have an impact on the stroke patient's level of motivation and rehabilitative outcome, we can suggest game design guidelines and ideas for designing and developing interactive games for stroke patients and rehabilitation. Table 1 lists the motivational factors of stroke patients and game design inputs and considerations for the game designers.

5. Gamified Solutions in Healthcare (GSH) - Virtual Nursing Home (VNH)

In our ongoing project called Gamified Solutions in Healthcare (GSH), we are developing services and solutions for elderly people through gamification or game-based activities. One of the goals in this project is to design and develop a Virtual Nursing Home concept. This conceptualization should offer alternative solutions for providing elderly's self-care, preventing elderly from loneliness and social isolation, and easing the healthcare professional's work load. Virtual Nursing Home (VNH) concept has been planned and designed with a close collaboration with Serious Games Finland, Puuha Group, and also with other public and private sector partners in Finland such as City of Turku and Attendo Oy. Basically, this concept includes four service areas: Socialization, Entertainment, Rehabilitation, and Counseling. These service areas have been conceptualized, designed, and analyzed based on our findings from the literature review, related studies, review of existing games, consultation with partnered organizations, and observational study at elderly service homes in Finland. At the initial stage of the study, we conducted the literature review study that covers the usability and usefulness of existing technologies, commercial games and our existing and on-going games, socialization and physical rehabilitation of elderly, and motivational factors for elderly in their rehabilitation. In this paper, we report the importance of motivational factors for elderly and how we can integrate these findings into our current and future games for VNH concept. Figure 1 mentions the conceptual diagram of Virtual Nursing Home.

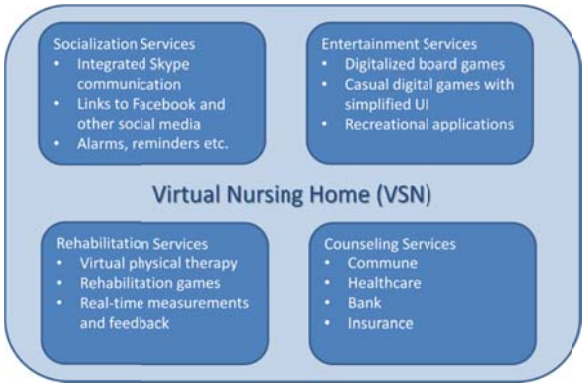

Figure 1. Overview of Virtual Nursing Home concept

We have started to design and develop the VNH system concept by using User Centric Design (UCD) and rapid prototyping research methods. UCD is defined as multidisciplinary design approach based on the active participation of targeted users in the design process for an in-depth understanding of users and their requirements. Design and evaluation processes can be iterative whenever it is necessary [28]. The rapid prototyping stage includes an early iteration loop that uncovers insightful feedback and ideas on system, technical design, interface issues, creativity in the system, and effectiveness of system's instruction [29]. UCD includes different stages: user requirements, requirements specification, prototyping, and evaluation. In this project, we will use rapid prototyping technique when we have information about functional and system requirements. With regard to the concepts that we have adopted in VNH system, the social services in the VNH system should bring new social tools especially for isolated patients to receive the social support not only from family members, relatives, and friends but also from doctors, therapists, and nurses. The examples of social tools are live video chat, reminder or alert system by family members or healthcare professional (e.g., to take medicine on the prescribed time, to take meal on the regular time, and to motivate elderly to do physical exercises), and monitoring system such as fall detection, movement detection, and emergency call. The social service tool should be able to integrate video and live chat system (e.g., Skype), elderly friendly social network tools, and powerful motion detection sensor (e.g., Microsoft Kinect). The concept of

rehabilitation services in VNH is to provide elderly people game-based physical activities for improving their physical well-being and promoting their daily or weekly exercises. Moreover, this concept aims at helping therapists or caregivers at the elderly service homes in Finland to reduce their workload in terms of rehabilitative and physical training for elderly. The concept of entertainment services that we planned in VNH is to support the elderly recreational and leisure activities that are needed in old age. The current practices that elderly perform at the service homes in Finland are group activities such as dance-along session, board games, sing-along, and arts-and-crafts. In VNH, we intend to create game-based digital recreational activities for the elderly to enhance their recreational and leisure experiences in their daily lives. The last concept in VNH system is counseling services that provide elderly variety of services such as healthcare, safety, banking, and insurance. To shape this concept, we are aiming at providing on-line based counseling sessions for elderly when they need to get it.

For the concept of social services, we have recently developed a social-based system which is called "Old Photos on Map Application". The main idea of this application is to maintain elderly's memories in their younger years and to enhance their positive emotions (e.g., happy, content) by showing personalized old photos on the digital map over the digital device such as mobile, tablet, and desktop. According to our previous study [30, 31], we have experiences to utilize old photos as an efficient way of storytelling for elderly to reflect their social background and memories and to enhance their socialization. We are now planning for our first user testing with older adults to understand the usability and usefulness of this system and how it can socially impact on the elderly and their emotion. Based on the findings from our future user testing, we will decide how we can integrate this system into our main concept of social services in VNH system.

In VNH system, Entertainment and Rehabilitation are the two important services. To achieve both concepts of entertainment and rehabilitation, we aim at designing and developing digital games that will address the needs of elderly's physical and recreational activities. At the early stage of this project, we are partnering with two organizations, Serious Games Finland and Puuha Group. Both of them are largely working in the area of serious gaming and digital games. The collaboration between our project and Serious Games Finland is to investigate the usability and usefulness of Kinect for Xbox One which is the newest version released from Microsoft. Currently, we are trying to test the commercial games that use Kinect as a motion sensor and how effective and efficient it is for elderly players. We are also testing the features provided in the up-to-date version of Kinect. In the spring 2014, we have tested with a few older adults by letting them play Kinect-based Xbox games to understand how effective and efficient Kinect for elderly is. In a close cooperation with Serious Games Finland, we are currently studying on virtual physical therapy solutions that can interpret the physical therapy and exercises movements. We are currently developing quick prototypes namely virtual swimming and seated exercises by utilizing exercise library. Once we have done these games, we aim at running pilot test with elderly to understand its usability and usefulness.

In addition, we are also closely working together with Puuha Group Finland. Basically, Puuha Group is designing and developing digital games for playground and public places with physical instruments or equipment. Their idea is to install such digital games with physical equipment in the playgrounds and public spaces in the neighborhood in Finland for people's physical well-being and recreational activities. We are also planning how we can adopt this idea in VNH concept and how we can deploy such games in real nursing homes or elderly service homes. Therefore, we are currently reviewing the existing games designed by Puuha Group whether these games are suitable and adaptable for elderly and improve their physical activities. The games that Puuha Group has developed are SportWall or PhysioWall and Resiina. All these games are targeted for physical activities of players but they are not targeted for elderly players. Thus, we are trying to test these existing games with old users whether they are elderly-friendly. Other than Finnish collaboration, we are also working with Japanese researcher in the area of digital games for elderly and healthcare. One of our visiting researchers has developed a game called "Top 100 Mountains game" that will be a totally new game which has some similarities to SportWall by Puuha Group but we will be focusing on Japanese culture (e.g., Samurai, Japanese Mountains, Shrines) because we have intention to conduct cross-culture test between Finland and Asian countries (e.g., Japan, Singapore). In this paper, we have reported a list of motivational factors for elderly and their rehabilitation. Since motivation plays a key role in rehabilitation, it is important to know how we can adopt these motivational factors in designing and developing games. We are currently at the stage of developing new games (e.g., Kinect-based games and Exercise Library with Serious Games Finland) and re-designing current games (SportWall or Physio Wall with Puuha Group). Therefore, we are developing the ideas of integrating motivational elements in the game design and gameplay. For example, we can design multiplayer games or intergenerational game to enhance the socialization of elderly player. We can design effective game level design from novice to professional player. Moreover, positive feedback, personalization, game music, game incentives, and game environment are also important motivational elements that need to be taken into consideration for game design and game play.

6. Preliminary Findings from Pilot User Testing

Based on the objectives of VNH project, it is important to investigate the usability and usefulness of existing games whether if they are suitable for elderly and for their physical activities and rehabilitation. Therefore, we conducted a pilot user testing with elderly participants who resides at the service homes or elderly homes in Rääkkylä, in the eastern part of Finland. We recruited five elderly participants who are physically and mentally sound, fairly active in exercises, and regular visitors to the service home. In this study, we selected non-commercial game, Puuha Group's SportWall, and commercial games; XBOX's climbing game and PS3's Tennis game respectively. Xbox's climbing game used Microsoft's motion-based Kinect sensor to play the game. PS3's Tennis game used PlayMove controller to interact the game while Puuha's SportWall used the traditional webcam to track the player's movements. The reason why we selected these games was to investigate the difference of usability and usefulness between commercial and non-commercial games. Besides, we would like to find out the usability of multimodal input devices that we used in this study. Basically, the commercial games are targeted for entertainment and for younger players. However, Puuha's SportWall game is designed for physical exercises and for various age groups. Therefore we tried to investigate whether the commercial games are suitable for elderly and their physical activities. Beside, we would like to find out if the non-commercial game, Puuha's SportWall, is also suitable for elderly players and their rehabilitative exercises. In this user testing, we let the individual elderly play a game in each game session. Before they played the game, we asked their consent to participate in this user testing. After that, we briefly explained the individual participant how to play the game by doing a game demonstration. All the elderly participants in this study lacked the prior experience in playing digital games. Thus, we assisted them in their first try so that they could easily perform the actual gameplay. In session one, the elderly participant had to play Xbox's climbing game. The gameplay took about 5 to 8 minutes followed by a quick questionnaire session that investigated their feedback towards the usability of games, input device, and their experiences in the particular game session. In the second game session, the elderly participant had to play PS3's tennis game followed by Puuha's SportWall game in the third session. We used the same procedures in all three sessions. After finishing all sessions, we conducted a quick follow-up interview session with the elderly participant to get their feedback on the overall gameplay experiences in this usability testing. The usability testing for each participant took about 30 minutes and the whole user testing took about 3 hours. In this study, we basically gathered the elderly participants' feedback towards the usability and usefulness of three game, interactive input devices, and their overall experiences. After collecting the elderly participants' responses, we compared the ease of use of commercial Xbox's Climbing game and PS3's Tennis game with SportWall game. Moreover, we compared the ease of use of multimodal input devices that were used to interact with the games.

Based on the feedback made by the elderly, we noticed that commercial games are hard for the elderly to play in terms of their user interfaces, graphics, and gameplay. Commercial games are typically containing too much information on the user interface such as graphic, text descriptions, and background music that are not suitable for the elderly. Most of the commercial games focus more on young and healthy players. Therefore, their game designs and interfaces are too much fanciful and complex for older players. Furthermore, these games cannot be customized for older players to adjust their limited mobility and movements. Based on the findings from the user testing, we have found out that most of the elderly participants in this pilot study could not follow the instructions given in the commercial games. Since they could not customize the game to meet their needs in mobility and physical movements, most of them did not complete the first level and they felt a bit frustrated to play it again. Besides, the feedback (e.g., scores and labels) in the game were lacking the motivational and encouraging messages to the elderly. Moreover, the feedback in the game was less appealing and not intuitive enough for the elderly player. Apart from the difficulties they have encountered in the gameplay, the elderly participants mentioned that they were interested in playing commercial games as their leisure activities as well as physical exercises. For example, they liked the idea of sport activities such as Climbing and Tennis games.

In contrast to the commercial games, the elderly participants gave the positive comments on the SportWall game. For example, they mentioned that the user interface of SportWall is simpler and cleaner than the commercial games. Therefore, they could focus on the game tasks with less distraction in the gameplay. The text descriptions in SportWall game are simple and visible enough for the elderly to see. As a result, they could follow the instructions to play the game easily. The personalization supported by the game could help the elderly to easily play the game that they were convenient with the level of difficulties and motoric levels. Comparing to the commercial games, they preferred SportWall game environment or game scene which is simple and appealing. The game feedback and scores displayed in the SportWall game were visible and clean enough so that they can easily understand their progress and performance. However, the elderly participants and the caregiver at the service home pointed out that some actions (e.g., Jump) in this game could lead the elderly to be fallen and elderly may become tired after some time. That is why, it is important to address some design issues in the Puuha's SportWall game that are not suitable for the elderly players. With regard to the multimodal input devices that we used in this study, we found out that the

elderly participants chose Xbox's motion-based Kinect sensor as the most effective device in playing game. In contrast, they claimed that PS3's PlayMove controller is the least effective in interacting with the game system because of its complications in pressing different buttons while they were playing. Therefore, it seems that controller-free interactive device is suitable for the elderly and their gameplay. However, it is important to conduct the usability study with larger sample size to be able to validate this finding. In general, the findings from our pilot user testing show that SportWall game is promising to be used for elderly's physical activity although there were some usability issues that need to be addressed. Figure 2 shows our pilot user testing with elderly participant. These preliminary findings are useful and insightful for our future design enhancement and development. Our future works includes the following:

1) To design and develop Kinect-based games that utilize the exercise library (e.g., Virtual swimming and Seated games)
2) To run the pilot test of these games with elderly patients
3) To re-design the current games by Puuha Game to be suitable for elderly player
4) To run the pilot test of Puuha Group games to investigate whether these games are elderly friendly
5) To run the pilot test of "Old Photos on Map Application" and to investigate its usability and usefulness
6) To decide how "Old Photos on Map Application" can fulfill the concept of social services in VNH system
7) To study the usability and usefulness the pilot test of "Top 100 Mountains game" and how it can be integrated into VNH system
8) To develop the ideas how we can adopt the motivational factors that we have found out in this literature review in our future game development and enhancement

Figure 2. A Pilot User Testing at Rääkkylä autumn 2014

7. Conclusion

We listed motivational factors of stroke patients' rehabilitation based on the literature. The factors are useful and insightful when designing digital games for stroke patients and their rehabilitation. We outlined game design considerations based on the motivational factors. Moreover, we have reported the four concepts: social services, rehabilitation services, entertainment services, and counseling services in our VNH system and how we can collaborate with partnered institutions. Currently, we are reviewing existing games from Puuha Group and developing new game concepts with Serious Games Finland. We have conducted our initial pilot user testing by using commercial games (Xbox's climbing game and PS3's tennis game) and non-commercial game (Puuha's SportWall game). The results showed that SportWall game has potential for elderly, but it is important to redesign to meet the needs of elderly. Moreover, the elderly participants claimed that they preferred the controller-free interactive device in the gameplay. Based on the findings from this pilot run, we will continue future enhancement and development followed by a larger usability testing with elderly at the service homes in Finland. Then, we will try to integrate the motivational factors that we reported in this paper into our new game design ideas in existing and new games.

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

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Abstract. In this study, we conducted the pre-studies of Gamified Solutions in Healthcare (GSH) project. The main objectives of these pre-studies are to understand game design guidelines, the usability of Kinect, commercial, and non-commercial games. In pre-study 1, we conducted a literature review of motivational factors for the elderly's physical rehabilitation. In pre-study 2, we reviewed commercial games for the elderly. We conducted a usability testing of Microsoft Kinect with eight elderly in pre-study 3. Then, in pre-study 4, we conducted a usability testing of Puuha's game and two commercial games with five elderly participants. The findings from the literature review of motivational factors provide us useful game design guidelines how to motivate the elderly. The findings from the review of commercial games highlight that commercial games lack important design guidelines for the elderly. We also learn from the usability testing that Kinect has the potential to be used as an input device for the elderly, but built-in gestures are difficult for the elderly. Finally, the findings from the usability testing of Puuha's game and two commercial games provide us insightful game design and usability guidelines for the elderly. These findings are useful for our future game development for the elderly.

Keywords: Usability · Exergames · Gamification · Human-computer interaction

1 Background

Playing games can help the elderly to improve their 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 and the younger generation [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].

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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 the 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.

In our 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 only on "Rehabilitation" service, which aims at promoting the elderly's physical well-being by utilizing game-based exercises. Before design and development of effective game-based exercises for the elderly, we conducted four pre-studies: a literature review, a review of commercial games, a pilot usability testing of Kinect, and a pilot usability testing of existing games. In the next sections, we will report the findings from these four pre-studies.

2 Pre-study 1: A Literature Review

In this literature review, we investigated the important factors that can influence on the motivation level of the elderly. Social functioning is regarded as one of the most important factors for the elderly's motivation [14–17]. 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 a game that has a goal-oriented level design to attract players from novice to professional levels.

Rehabilitative environment is 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 (e.g., household environment, park, and shopping mall). In physical rehabilitation, the individual motoric level can be different from one player to another. That is why, customization is important in rehabilitation [21]. When we create digital games for the elderly's rehabilitation, we need to take into account that customization 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. 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 - Intergenerational game - Virtual friend - Video chat in game - Social-networking game
Patient-therapist Relationship	- Virtual therapist - Virtual nurse - Virtual Coach
Goal setting	- Level design - Perceivable and achievable goals
Rehabilitative setting and environment	- Game theme and scenery - Difficulty of the game - Complexity of the game
Information from Healthcare Professionals	- Game tutorials - Game introduction - Help system - Computer-controlled assistant

3 Pre-study 2: A Review of Commercial Games

In this pre-study 2, we review existing games available in the market and research. First of all, we found 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, the elderly can not only play the game but also socialize through the gameplay. Moreover, the Wii Sports games are promising for the 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 the mental and social well-being of the elderly. They conducted a pilot study with 14 pairs of elderly-teenager participants, and reported that Wii games can bridge the inter-generational gap between older and young people.

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 the 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.

With respect to setting a relevant rehabilitative goal, this concept can be also seen in Nintendo Wii's My Fitness Coach game. In this game, 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 it allows players to earn game scores or points that can unlock new costumes and songs in the game itself.

The familiarity with the rehabilitative setting and environment is one of the most important factors for the elderly's motivation. In the gaming market, there are a number of physical game-based exercises 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.

Real-world activity games are likely to enhance players' motivation and engagement. There are many games in the market 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 are 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 provide customization in the game. Apart from VirtualRehab

games, most of the games available in the market are targeted for healthy and young players. Therefore, the customization of these games is not elderly-friendly.

With regard to the positive feedback for the elderly, 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 regardless of their performance.

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 players. 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 players 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 the elderly and their physical rehabilitation. Although there are a number of games that have the potential for the elderly's physical rehabilitation, they still lack proper game designs to motivate the elderly. For example, Nintendo Wii's Sports games have the potential to train the elderly to improve their movements in rehabilitation but these games are not well-designed in customization that can be adjusted according to the elderly's ability in movements, range-of-motions, and strength. The findings from this literature review study highlight the design issues of commercial games in the market. It also helps us to understand insightful game design guidelines that are important for our future development phase.

4 Pre-study 3: A Pilot Usability Testing of Kinect

4.1 Kinect for Healthcare Games

Multimodal input devices 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.

According to Microsoft's Xbox [25], 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, and being recognized and signed-in

automatically. Since the first generation of Kinect was introduced, 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, the 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 the 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 et al. [13], they report that Kinect is an efficient and effective way of interaction for the elderly to play the rehabilitative games. Pisan et al. [26] mention 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 [27] points out that Kinect is the front-runner in the market because it provides the natural movements of human body and it is the most feasible technology for exergaming.

Generally, Kinect is financially affordable and medically beneficial to the ageing society [28]. According to Ganesan and Anthony [28], they developed a 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. [29] report 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 min sessions. In this study, we investigated the usability of Kinect for Xbox for the elderly. The details of usability testing and the findings are reported in the next sections.

4.2 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 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 aged between 64 and 78. Most of them are currently residing at the service home, whereas the rest are the regular visitors 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 h per week for doing physical exercises while the other half spend more than 6 h 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 smartphone. 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 includes 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 Table 2.

Table 2. Kinect-based tasks.

Task	Description
Wave to Kinect	Move 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
Make a selection	Move your hand over a specific item or tile
Scroll through a screen	When the hand icon appears on the screen, close your hand anywhere over the area you want to scroll. Move your hand to the left or right to pull the screen in that direction
Return to home	Hold out both of your hands towards the edge of the screen. 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 Move your closed hands towards the edge of the screen and in the end, open your hands
Zoom in	When the hand icon appears on the screen, close your hand over the area you want to zoom Pull your hand toward you to zoom the screen in
Zoom out	When the hand icon appears on the screen, close your hand over the area you want to zoom Push your hand away from your body to zoom the screen out
Open the system menu -skype	Move the hand cursor over the Skype button Extend your arm forward toward the Kinect and hold until a circle timer appears 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	Move the hand cursor over the Skype button Extend your arm forward toward the Kinect and hold until a circle timer appears After the ring has filled, you'll see the system menu. Select Snap from the menu

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

4.3 Findings and Discussion

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 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

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

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 participants (P1, P2, P5, and P6) have no failed attempts in this tutorial. The participant 3 (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 only succeed a single task "Wave to Kinect". Table 5 shows the average score and standard deviation of each task in this tutorial.

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 smartphones. However, there is no evidence seen in the findings whether their prior experiences can influence on this performance in this tutorial.

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. 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 through adequate training. They reveal their interests in using this sensor in interacting with computers. Table 6 shows the average scores of the usability of Kinect.

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

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 the questionnaires (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. 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.

This Kinect usability testing session highlights some important findings. Firstly, the elderly participants who have prior experiences in using computer, tablets, and smartphones can efficiently use the Kinect sensor. However, there is no evidence of a 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 a 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 the elderly to control the Kinect sensor. From this study, we can learn that it is important to design user-friendly gestures when we use Kinect sensor for the elderly. The limitation of our study is that the sample size is small.

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

5.1 A Pilot Usability Testing

In this study, we conducted 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. 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 a 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 a 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 games are suitable for the elderly and their physical activities. Figure 1 shows a screenshot of Puuha's SportWall 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 this 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 min in standing position to play the games. Before the elderly played the games, the researcher asked pre-interview questions. 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

Fig. 1. Puuha's game

game tutorial session, he or she played a particular game for five minutes, followed by a questionnaire session in which the 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, the 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 the individual elderly participant. Figure 2 shows a photo from the usability testing of existing games.

Fig. 2. Usability testing

5.2 Findings and Discussion

The findings show that commercial games are not user-friendly for the elderly. We investigated that the user interfaces, game contexts and contents, and gameplay in the commercial games are not suitable for the elderly. In Xbox's Climbing game, the elderly were distracted by the game contents such as user interface, icons, feedback, and game audios. Due to the complex game interface, it affected the elderly's gameplay and sometimes, they did not know how to continue 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 the game because of the 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, 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 continue the gameplay. Based on the findings from the post-game interview sessions, the elderly participants mentioned that they had fun in playing 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 a trainer. In general, they advocated that digital games seem to be an effective way of exercising for their physical well-being.

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 the 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 the 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.

6 Conclusion

In this study, we conducted the pre-studies of GSH project. We conducted pre-study 1–a literature review on motivational factors for the elderly in rehabilitation. The findings from this literature review highlight insightful game design guidelines how to motivate the elderly. In pre-study 2–a review of commercial games, we reviewed if commercial games provide motivational game designs for the elderly. The findings highlight that the majority of commercial games are not designed for the elderly although they

provide some motivational game designs such as multiplayer game and the real-life environment. These findings provide us insightful knowledge of what is required for the elderly in our future game development. In pre-study 3–a usability of Kinect sensor, we evaluated it with elderly participants. The findings show that Kinect has a potential to be used as an input device for the elderly although its built-in gestures are difficult for the elderly. We also learn that it is important to implement elderly-friendly gestures in our future development. In pre-study 4–we evaluated our existing Puuha's game and two commercial games: Xbox Climbing game and PlayStation's Tennis game. The findings from this usability testing show that commercial games are not suitable for the elderly because of their clutter interface, graphics, and gameplay. We also learn that Microsoft Kinect is the most effective input device for the elderly to play a game.

The findings from these pre-studies provide us insightful design guidelines for designing games for the elderly. We also found out the usability of existing commercial games and input devices for the elderly. The usability guidelines from these studies provide us important 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.

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When Japanese Elderly People Play a Finnish Physical Exercise Game: A Usability Study

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Abstract

In this paper, we report the findings from the usability testing of the Finnish Skiing Game with 24 Japanese elderly participants at the Sendai City Health Promotion Center in Japan. The main objective of the study is to investigate the participants' feedback towards the usability of the Skiing Game, which was originally designed and developed for elderly Finnish people. We also investigated the Japanese elderly participants' game experiences during and after the gameplay. The findings show that the Skiing Game was an easy and user-friendly game for the elderly participants. Their gameplay experiences during and after the game session were fairly positive. Most of the participants were interested in the gameplay, and they agreed that digital games could be an effective way of exercising. In this study, we observed that the Finnish Skiing Game is a suitable game for the elderly Japanese people because of its simple interface, easy game action, and friendly game context. In this paper, we provide the usability guidelines and recommendations that we learned from this study.

Keywords

usability, user experiences, human-computer interaction, physical exercise game, game localization

Introduction

According to the World Health Organization (WHO, 2011), being engaged in physical activities can improve the elderly's physical fitness, functional health, and cognitive ability. Basically, physical activities include leisure activities (e.g., gardening, dancing, and walking), activities of daily living (e.g., meal preparation and dressing), playing games, and participating in regular exercises routines. Bherer, Erickson, and Liu-Ambrose (2013) advocated that physical exercise is an effective non-pharmaceutical intervention for the elderly to prevent cognitive decline and neurodegenerative disease (e.g., Alzheimer's disease). The effects of physical exercises on the elderly are not only prevention of age-related diseases (e.g., heart disease and diabetes) but also an improvement in the quality of life (e.g., independence; Sun, Norma, & While, 2013).

Participation and engagement in regular physical exercises can decline when a person becomes old (Factora, 2013). Milanović et al. (2013) indicated that the ageing process can reduce the physical fitness of the elderly such as strength, endurance, agility, and flexibility. As a result, the elderly may encounter difficulties in the activities of daily living and functional ability. The American Psychological Association (2016) pointed out that most elderly people experience natural and normal age-related changes that include physical and functional decline. This can impact the quality of life for the elderly.

People from different areas such as healthcare, digital media, and physiotherapy, have become interested in helping the elderly to improve their active participation in regular physical exercises by using the latest technologies. For example, in recent years, healthcare practitioners and researchers have become interested in digital games as an alternative way of physical exercises for the elderly (Alankus, Lazar, May, & Kelleher, 2010; Gerling, Livingston, Nacke, & Mandryk, 2012; Uzor & Baillie, 2014). Different terms are used to define the concept of game-based exercises for the elderly such as *serious games for healthcare* (Tashiro, 2009), *exergames* (Brox, Burkow, Evertsen, Åsheim-Olsen, & Vognild, 2014), and *gamification for healthcare* (Brauner, Valdez, Schroeder, & Ziefle, 2013).

To date, many researchers have studied the usability and usefulness of existing games and technologies for the elderly's healthcare such as Nintendo Wii Fitness games (Kahlbaugha, Sperandioa, & Ashley, 2011; Theng, Chua, & Pham, 2012), Kinect for Xbox Fitness games (Ganesan & Anthony, 2012), and PlayStation PlayMove Fitness games (Pyae, Luimula, & Smed, 2016). Furthermore, virtual reality and augmented reality games are also being used to improve the elderly's motivation and engagement in their daily exercises (Halton, 2008; Pyae, Tan, & Mark, 2013). IJsselsteijn, Nap, & de Kort (2007) mentioned that the digital game market for the elderly is significantly large because game developers primarily focus on adolescent users, and commercial games do not meet the needs, abilities, and limitations of elderly people. The authors of this paper also pointed out that the elderly encounter more usability problems in digital games, compared to younger users because of their limited functionality and lack of technological experiences (IJsselsteijn et al., 2007).

There are many studies that investigated the usability of digital games for the elderly and their user experiences (Marin, Lawrence, Navarro, & Sax, 2011). Silva and Nunes (2010) also pointed out that although there are an increasing number of studies on usability guidelines for users in various contexts, little is known for usability guidelines for the elderly in digital games. To date, there are some promising and insightful findings from the usability testing of digital games for the elderly (Gerling, Schild, & Masuch, 2010; Nawaz et al., 2015). However, this is an on-going process, and it is important to study more widely in this area. The better we investigate the usability of digital games for the elderly, the more we will gain insightful design guidelines that will also help the future research in related areas.

In this paper, we present the background of our project called *Gamified Solutions in Healthcare (GSH)*. We explain the concept of the Skiing Game and its technology. Then, we mention the design and procedures of the usability testing of the Skiing Game, which is conducted with 24 Japanese elderly participants in Japan. After that, the results from the usability testing are reported in the Data Analysis section. The findings from this usability testing are reported in the Discussion section. We also recommend usability design guidelines that can be useful not only for our future design, development, and usability testing but also for practitioners in the same area.

The main objectives of this paper are

- to report the findings from the usability testing of the Finnish Skiing Game with Japanese elderly people, and
- to recommend usability design guidelines for our future development and other practitioners in a related area.

Background

Gamified Solutions in Healthcare (GSH) is a Tekes-funded research project, which is the collaboration between Turku University of Applied Sciences and University of Turku, Finland. We are closely working with our industry partners such as GoodLife Technology Finland and Puuha Group Finland. We also have public and private sector partners such as Attendo Group and the City of Turku that helped us recruit elderly participants in our usability testing. The main objective of GSH is to provide gamified services and solutions for the elderly to improve their quality of life in terms of active ageing, cost-effective healthcare solutions, better socialization, and their safety (Raitoharju, Luimula, Pyae, Pitkäkangas, & Smed, 2014).

The core concept in this project is called *Virtual Nursing Home (VSN)*, and it includes four major services for the elderly: Socialization, Entertainment, Counseling, and Rehabilitation. The Socialization service focuses on promoting an elderly persons' socializing experiences through gamification. The Entertainment service aims at promoting the elderly's recreation through gamified activities. The Counseling service includes interactive counseling services such as information on banking, healthcare, and safety for the elderly. The Rehabilitation service utilizes gamified exercises for the elderly's physical fitness and rehabilitation.

In this paper, we only emphasize the Rehabilitation service. The main objective of this service is to provide game-based exercises for the elderly to improve their engagement and motivation in daily or weekly physical exercises. Furthermore, we aim at providing effective exercises for the elderly who are going through rehabilitative training. Figure 1 shows an overview of the VSN concept (Pyae et al., 2015a, 2015b).

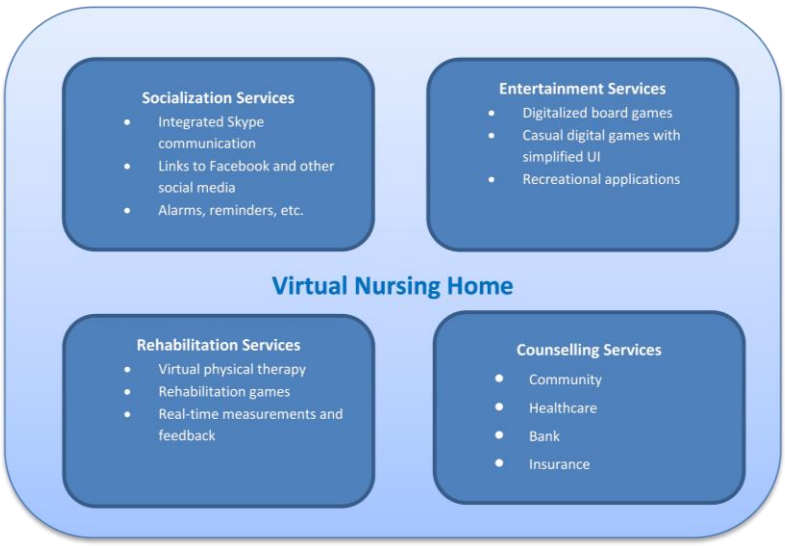

Figure 1. The overview of VSN concept.

Before we designed and developed digital games for the Rehabilitation service for the elderly, we conducted preliminary studies to understand the elderly's requirements for physical activities and the potential of commercial and existing games for physical exercises for the elderly. The findings from the preliminary studies were reported in the previous research publications: a literature review on digital games for the elderly (Raitoharju et al., 2014), understanding

motivational factors for the elderly (Pyae et al., 2015a), a review of existing game technologies and commercial games (Raitoharju et al., 2014), usability testing of commercial games, and SportWall game developed by Puuha Group Finland (Pyae et al., 2015a, ; Pyae, Luimula, & Smed, 2016; Pyae, Raitoharju, Luimula, Pitkäkangas, & Smed, 2016). The findings from the preliminary studies are useful and insightful for our game design, development, and future usability testing of games for GSH.

The game industry today is no longer targeting a particular user group in a specific country or region. Game localization and culturalization have become a trend in today's digital game market. According to Skoog (2012), localization (as it pertains to gaming) is defined as the adaptation of digital games for different markets of specific regions (e.g., Asia, Europe, and America). Localization includes changing game components, not only graphics, but also cultural references. Localization is a means to provide a game for players in different regions to enjoy without losing the originality of the games. It can also add local cultural values while being in compliance with the legal and regulatory requirements of a specific country.

David, Curran, and Simon (2005) advocated that to expand the sales of a particular game across different countries, the effort for localization needs to be more sensitive to local customs, tastes, rules, and regulations. Salen and Zimmerman (2006) also pointed out that games can reflect the specific values of a particular society or cultural group, and a game can miss important cultural values unless the game designers or artists engage the games with the cultural representation. Chandler and Deming (2011) defined that "culturalization" is more than a simple localization; it takes a closer and deeper look into a game's contents and assumptions, and looks at the viability in both multicultural marketplace and different geographical locations.

One of the main objectives of the GSH project is to evaluate our games with not only the Finnish elderly but also the elderly in different countries. Although our game is designed for the Finnish elderly, we would like to investigate whether the game is also suitable and user-friendly for the elderly living in different countries and different cultural groups. One of the goals of our project is to partner with other foreign organizations to understand how we can localize our games in different countries. For instance, we are closely working with Japanese game companies and social organizations that specialize in the elderly's well-being. The objectives of the usability testing of the Skiing Game with the Japanese elderly are

- to investigate the Japanese elderly's feedback towards the usability of the Skiing Game,
- to investigate the Japanese elderly's game experiences during and after the gameplay, and
- to understand their general feedback towards the game.

Skiing Game

In this study, we developed a physical exercise game called Skiing Game, which was designed for the Finnish elderly to improve their motivation and engagement in regular physical exercises. The main objectives of the Skiing Game are to provide a user-friendly, simple, easy, and effective exercise game for the elderly and to encourage them to engage in regular physical activities.

Based on the findings from the requirements gathering (Pyae et al., 2015a, 2015b; Raitoharju et al., 2014), we found out that game context and background should be familiar to the elderly because the elderly prefer game context and background that are close to real-life environments and activities. For instance, they like to play card games, sport-based games, and recreational games (e.g., dancing and singing games). Moreover, we realized that they like user-friendly and natural game actions, which can be familiar to them (Pyae et al., 2015b). For example, they like tennis, bowling, and dancing game actions. According to the observations from the previous usability testing (Pyae, Luimula, & Smed, 2016), we found out that simple, easy, and effective interaction techniques are important for the elderly when playing a game. They prefer controller-free natural movements when playing games (e.g., a motion detection device). The elderly participants also recommended simple and easy in-game instructions to follow. Furthermore, they preferred simple and clear feedback that makes the game easy to understand.

Based on the design guidelines mentioned above, we designed a skiing-based exercise game where we chose snowy mountains and a forest as the game context and background. The main reason we chose this type of sport is that skiing as an activity is familiar to most Finnish elderly people. The gameplay is simply based on steering a pair of skiing poles (double pole skiing technique). This game is relatively easy and is a familiar exercise technique to the Finnish elderly who have previous experiences with cross-country skiing. We used a traditional webcam based controller-free interaction. We also designed simple game labels, instructions, and the ability to provide feedback in the game.

The Skiing Game was designed and developed using a Unity 3D game engine. The player has to complete a simple calibration before the gameplay. When a player starts playing the game, he or she needs to ski through gates and to reach the finishing line in a given time. There are many obstacles to avoid along the way, which can cause the player to fall down in the game. To control the game the player needs to hold both hands (double pole skiing motion) as the way he or she is steering a pair of skiing poles, left and right. To move forward, the player needs to continuously move both hands forward and backward. To accelerate the movement, the player has to perform this action faster. The more the player moves both hands, the faster the movement becomes. It is important for the player to follow the skiing trail displayed in the game. To move left or right, the player simply needs to move his or her body to the left or right. In the uphill and downhill sections of the game, the player needs to accelerate more or to slow down. When the player reaches the finishing line, the score screen will pop up, showing the player's time and the number of gates the player successfully went through. See Figure 2 for screenshots from the Skiing Game.

Figure 2. Screenshots from the Skiing Game.

For the game interaction, we used a webcam with Extreme Reality (XTR3D) Technology to track the player's upper-limb movements. Extreme Reality includes the technology that supports software-based motion analysis. It can control any computing device by using a traditional web-camera (Extreme Reality Technology, 2015). XTR3D includes a motion capture engine that detects the 3D position (X, Y, and Z) of a player's skeletal position just in front of the camera in every frame. After that, it creates a live 3D model of the player that is analyzed by the software

to recognize the gestures from the skeletal positioning of the player. The overview of XTR3D is shown in Figure 3.

Figure 3. The overview of XTR3D. Reprinted with permission from Extreme Reality Technology, 2015.

Usability Study

To test the Skiing Game with the elderly participants in different countries, we collaborated with our Japanese counterparts: the Sendai City Health Promotion Center and the Sendai-Finland Wellbeing Center in Japan. The Sendai City Health Promotion Center, operated by the Sendai City Health and Welfare Organization, is a rehabilitation center that provides rehabilitative training for the Japanese elderly. The Sendai-Finland Wellbeing center is a technology hub for the Finnish health informatics, and it also has a nursing home that provides elderly care including physical, social, and healthcare activities. Both organizations are interested in utilizing digital game-based intervention for the elderly to improve their physical exercises.

Elderly Participant Recruitment

The recruitment of the Japanese elderly participants in this study was mainly done by the physiotherapists from the Sendai City Health Promotion Center. They advertised the recruitment at their nursing home. The selection of the participants was based on certain inclusion criteria. For instance, the age requirement for the participants was between 60 to 85 years. The health condition of the participants needed to be stable. Moreover, they needed to be physically and mentally capable, with no neurological or cognitive deficits, of playing the game for at least 15 minutes. The wheelchair-bound elderly were excluded in our study because the game required players to stand during the gameplay. Participants needed to have the capability of independent standing and walking 10 meters. The physiotherapist from the center selected the elderly participants carefully to meet the needs of the study. We also requested the consent from each and every participant in this study.

Usability Test Design and Procedure

After recruiting 24 Japanese elderly participants, we conducted the two-day usability testing. On the first day, 16 participants played the game and answered the questionnaires. The remaining eight participants joined the usability testing on the second day. There were a total of five researchers who conducted the usability testing: three Japanese physiotherapists from the Sendai City Health Promotion center, one project officer from the Sendai-Finland Wellbeing Center, and one Finnish researcher from Turku University of Applied Sciences, Finland. The usability testing took place at a therapy training room at the Sendai City Health Promotion center. The whole study was conducted by using the Japanese language. Our Finnish researcher guided and monitored the whole study. There were three stations in three different rooms. At station one (room 1), one Japanese physiotherapist from the Sendai City Health promotion center conducted the pre-study interview that included the participants' demographic information, health background, their physical exercise activities, and their consent. It took about 5 to 10 minutes to ask the questions.

Station two (room 2) was operated by the two Japanese physiotherapists from the Sendai City Health Promotion center. At this station, the participants played the Skiing Game. One therapist guided participants on how to play the game, and the other monitored the participants to minimize their health risks. With regard to the gameplay by the participants at station two, one physiotherapist guided them on how to play the game before they played it. While they were playing the game, the therapist gave support if they needed it. The total time for station two

took about 20 minutes. In station three (room 3), the project officer from the Sendai-Finland Wellbeing Center asked (in Japanese) the participants to complete the post-gameplay questionnaires, which were also in Japanese. One student from the Sendai National College of Technology helped in videotaping the whole study. The detailed procedures of the whole study are mentioned in Table 1.

Table 1. Skiing Game Usability Testing Design and Procedures

Activity	Duration	Station
Introduction to the usability testing	10 mins	1
Pre-gameplay interview and consent taking		
Game Tutorial guided by the physiotherapist	20 mins	2
Skiing Game played by participants		
Break-time	5 mins	
Post-gameplay questionnaire	10 mins	3
Total	45 mins	

System Usability Scale (SUS)

To investigate the participants' feedback towards the usability of the Skiing Game, we used the System Usability Scale (SUS), which is easy and simple to understand for the elderly. SUS includes a 10-item questionnaire that gives the subjective assessments of the usability of a particular system (Brooke, 1996). SUS is based on the 5-point Likert scale from *Strongly disagree* (1) to *Strongly agree* (5). SUS can be used to evaluate a variety of products and services, which includes software and hardware systems, mobile devices, applications, and websites ("System Usability Scale (SUS)", n.d.). We can use this scale for a small sample size, and it is easy to apply to participants. Sauro (2011) mentioned that while SUS is intended to measure perceived ease-of-use of a system, it can also provide not only usability but also learnability dimensions. According to Brooke (2013), SUS is technology-neutral, and it has been continuously used as technology develops over the years without reinvention of questionnaires. Bangor, Kortum, and Miller (2009) mentioned that SUS is an effective tool for measuring the usability of a system or product, and it provides a score from 0 to 100, which is easy to understand for participants. Bangor, Kortum, and Miller (2008) advocated that SUS is a highly robust and flexible tool for usability practitioners. In this study, we modified the SUS questionnaires to suit our study. For instance, the original version of SUS refers to a particular system, and we modified it to a game system and its usability. Table 2 shows the revised version of the SUS questionnaires that are used in our usability testing of the Skiing Game.

Table 2. System Usability Scale (SUS) Modified for This Study

Questionnaires
1. I think that I would like to play this game frequently.
2. I found this game unnecessarily complex.
3. I thought this game was easy to play.
4. I think that I would need the support of a technical person to be able to play this game.
5. I found the various functions in this game were well integrated.
6. I thought there was too much inconsistency in this game.
7. I would imagine that most people would learn to play this game very quickly.
8. I found this game very cumbersome to play.
9. I felt very confident playing this game.
10. I needed to learn a lot of things before I could get going with this game.

Game Experience Questionnaires (GEQ)

In this usability testing, we used GEQ to understand the participants' experiences during and after the gameplay. We used two GEQ modules to assess the player's experience: in-game and post-game (IJsselsteijn et al., 2015a). The GEQ in-game module is used to assess a player's game experience during a game-play session. It includes seven components: Sensory and Imaginative Immersion, Flow, Competence, Positive Affect, Negative Affect, Tension, and Challenge (de Kort, IJsselsteijn, & Poels, 2007; Poels, de Kort, & IJsselsteijn, 2007). Norman (2013) advocated that GEQ is a reasonable and applicable questionnaire in exploring a player's experiences with a game. Norman also advocated that the GEQ questionnaire has been widely and successfully used in many studies internationally (2013).

Johnson, Wyeth, Sweetser, and Gardner (2012) mentioned that the components—Competence, Tension, Negative Affect, and Positive Affect—are easily understood by their titles. Competence refers to a player's skills and success in playing the game (e.g., I felt skillful). The component Tension is about a player's frustration in playing the game (e.g., I feel frustrated). Positive Affect is when a play feels positive (e.g., I felt good), whereas Negative Affect refers to the negative feeling a player may experience while playing the game (e.g., I felt bored). The component Challenge means the effort, challenge, and pressure felt by a player in the game (e.g., I had to put a lot of effort into it), and Sensory and Imaginative Immersion means how interested a player is in the game's story (e.g., I was interested in the game's story; Johnson et al., 2012). The component Flow is about how engrossed a player feels while playing the game (e.g., I felt completely absorbed). All GEQ in-game components and response options from the questionnaires are mentioned in Table 3.

Table 3. In-Game GEQ Components and Response Options from the Questionnaires

In-game GEQ components	Response option
Sensory and Imaginative Immersion	I was interested in the game's story. I found it impressive.
Flow	I forgot everything around me. I felt completely absorbed.
Competence	I felt successful. I felt skillful.
Positive affect	I felt content. I felt good.
Negative affect	I felt bored. I found it tiresome.
Tension	I felt frustrated. I feel irritable.
Challenge	I felt challenged. I had to put a lot of effort into it.

Regarding the GEQ post-game questionnaire, it is used to assess how players felt after they have played the game (IJsselsteijn et al., 2015a, 2015b). It has four components: Positive Experience, Negative Experience, Tiredness, and Returning to Reality. Basically, the Positive Experience component is about a player's positive experiences after playing the game such as satisfaction, victory, and power (e.g., I felt satisfied). In contrast, Negative Experience is about a player's bad experiences after he or she has played the game (e.g., I felt bad). The component Tiredness refers to a player's exhaustion in the gameplay (e.g., I felt exhausted). Returning to Reality is about a player's disorientation after he or she has played the game (e.g., I found it hard to get back to reality). In this study, for both GEQ in-game and post-game questionnaires, we use a 5-point Likert scale from *Not at all* (0) to *Extremely* (4). All GEQ post-game components and response options from the questionnaires can be seen in Table 4.

Table 4. Post-Game GEQ Components and Response Options from the Questionnaires

Post-game GEQ components	Response option
Positive Experience	I felt revived. It felt like a victory. I felt energized. I felt satisfied. I felt powerful. I felt proud.
Negative Experience	I felt bad. I felt guilty. I found it a waste of time. I felt that I could have done more useful things. I felt regret. I felt ashamed.
Tiredness	I felt exhausted. I felt weary.
Returning to Reality	I found it hard to get back to reality. I felt disoriented. I had a sense that I had returned from a journey.

Post-Gameplay Interview Questions

The post-gameplay interview questions were based on the Senior Technology Acceptance & Adoption Model (STAM; Renaud & van Biljon, 2008).The questions include the following four items that investigate the elderly participants' perceptions after playing the game:

- Perceived Usefulness was used to understand the effectiveness and usefulness of playing digital games.
- Perceived Ease-of-Use was used to find out if playing the Skiing Game was easy for them.
- Gerontechnology Self-Efficacy was used to find out if the player could easily play after receiving the game instructions and to determine if the game instructions were adequate.
- Gerontechnology Anxiety was used to investigate if the player was afraid of making mistakes during the gameplay.

Table 5 shows the post-gameplay interview questions. Figure 4 shows a photo taken during the gameplay.

Table 5. Post-Gameplay Questionnaires

Post-gameplay questions	
Perceived Usefulness	Could playing digital games be an effective and effortless way of exercising?
Perceived Ease-of-Use	Was playing the game easy?
Gerontechnology Self-Efficacy	Were you able to play the game after receiving instructions? Would the user instructions have been adequate?
Gerontechnology Anxiety	Were you afraid of making mistakes when playing the game?

Figure 4. Skiing Game usability testing.

Data Analysis

From the pre-gameplay interview sessions, we observed that all the elderly participants in this study performed regular exercises daily and weekly. They were active in physical exercises, which included walking, stretching, playing golf, and gardening. They exercised either at home or at the sports club. In this study, half of the participants (12 out of 24) had not played digital games before, and they did not have knowledge about digital games. The remaining 12 participants had prior experiences with digital games. However, six of them had negative game experiences. They claimed that games are difficult to play and are not interesting. The other six participants who had prior gameplay experiences enjoyed playing digital games, and they played often. They normally used a PC, tablet, or notebook to play digital games. The digital games they played were card games and memory games.

We present the findings from the analysis of in-game and post-game GEQ questionnaires data in Table 6 and Table 7. The average score of each component in both the in-game and post-game questionnaires was calculated according to the original GEQ assessment method (IJsselsteijn et al., 2015a). As shown in Table 6, the highest score of the in-game module can be seen for the Flow component (M = 3.0), followed by the second highest for the Positive Affect component (M = 2.9). In contrast, the Negative Affect component produced the lowest score (M = 0.4). With respect to the Tension component, it was the second lowest among other components (M = 0.8). The mean scores of the Competence component (M = 2.6), Sensory and Imaginative Immersion (M = 2.7), and Challenge components (M = 2.4) were greater than the average score (M = 2.0). Figure 5 shows the graphical presentation of the GEQ in-game mean scores and the standard errors.

Table 6. In-Game GEQ Mean Scores and the Standard Errors

In-game GEQ Questionnaire	Mean score (M)	Standard error (SE)
Flow	3.0	0.21
Positive Affect	2.9	0.14
Sensory and Imaginative Immersion	2.7	0.17
Competence	2.6	0.16
Challenge	2.4	0.21
Tension	0.8	0.16
Negative Affect	0.4	0.10

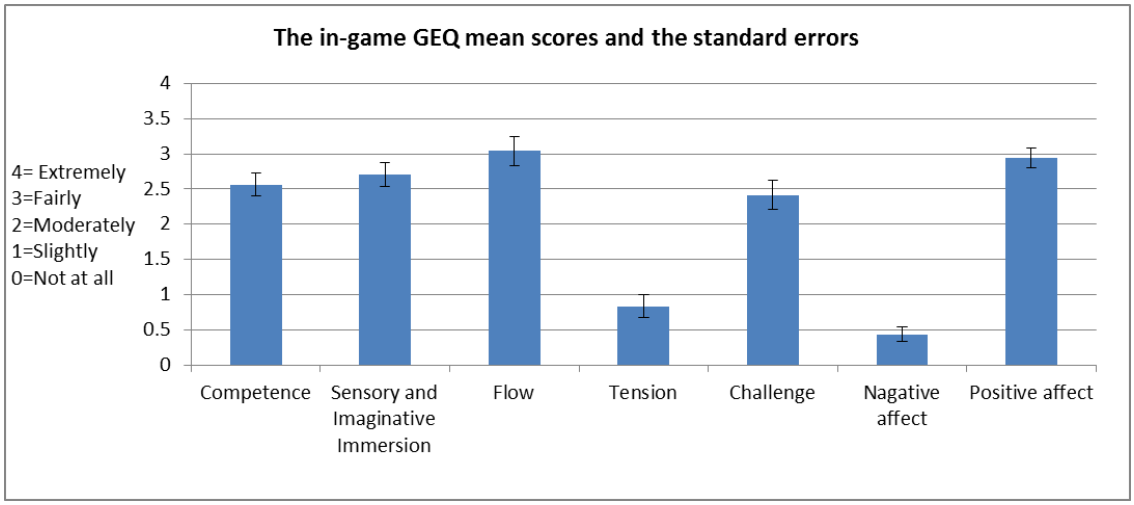

Figure 5. The in-game GEQ mean scores and the standard errors.

Regarding the findings from the post-game GEQ questionnaires, we can see that the Positive Experiences of the participants after the gameplay was about the average score (M = 2.1), whereas the Negative Experiences and Tiredness had the least average scores (M = 0.5 and M = 0.4, respectively). The Returning to Reality was also considerably low (M = 0.9).The results from the post-game GEQ questionnaires in this study are shown in Table 7. Figure 6 illustrates the post-game GES mean scores and the standard errors.

Table 7. Post-Game GEQ Mean Scores and the Standard Errors

Post-game GEQ components	Mean score	Standard error
Positive Experience	2.1	0.21
Returning to Reality	0.9	0.12
Negative Experience	0.5	0.10
Tiredness	0.4	0.10

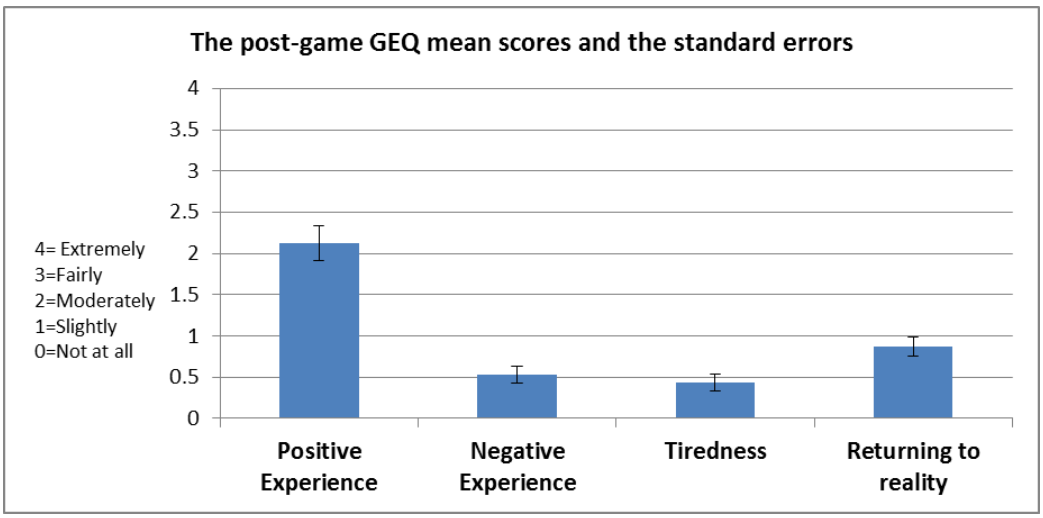

Figure 6. The post-game GEQ mean scores and the standard errors.

We analyzed the correlations between the Positive and Negative Affect in the in-game GEQ, and the Positive and Negative Experiences in the post-game GEQ. There are no correlations between the in-game and post-game GEQ variables except for the Positive Affect in the in-game GEQ and Positive Experience in the post-game GEQ. They have a positive correlation, as expected, and the correlation coefficient value is 0.72. Table 8 shows the correlations between the in-game Positive and Negative Affect, and the post-game Positive and Negative Experiences. Figure 7 shows a scatterplot diagram that illustrates the correlation between the in-game Positive Affect and the post-game Positive Experience.

Table 8. Correlations Between In-Game and Post-Game GEQ Variables

	Negative affect	**Positive affect**	**Positive experience**	**Negative experience**
Negative Affect	1			
Positive Affect	-0.31	1		
Positive Experience	-0.24	0.72	1	
Negative Experience	0.03	0.11	0.3	1

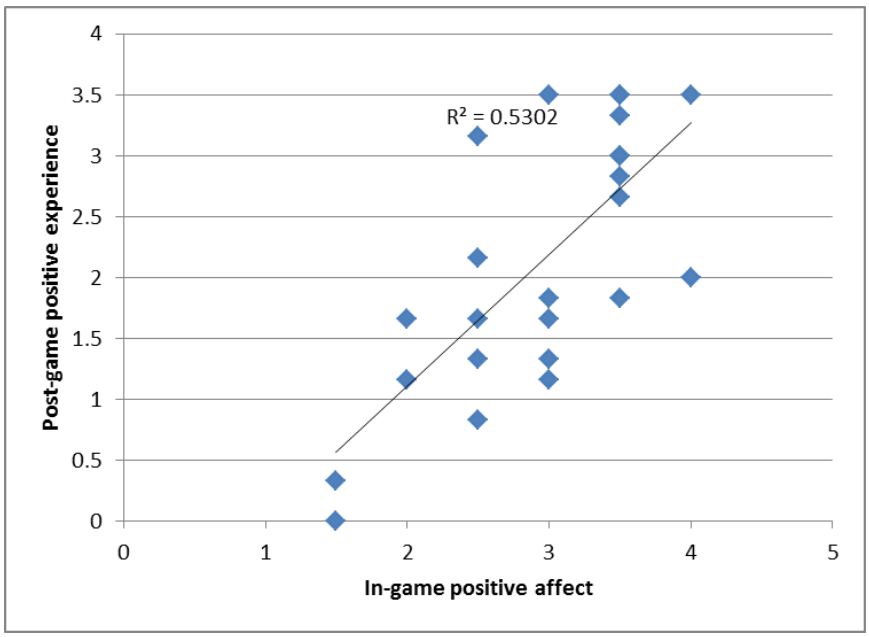

Figure 7. A scatterplot diagram of the correlation between the in-game Positive Affect and the post-game Positive Experience.

To report the participants' feedback towards the usability of the Skiing Game, we analyzed the SUS questionnaires data based on the calculation method mentioned in the original test (Brooke, 1996). We gave a score, which ranges from 0 to 100, to the individual participants. Basically, a SUS score lower than 68 was ranked as *Below Average*, and a score higher than 68 was considered *Above Average* (Sauro, 2011, "System Usability Scale (SUS)," n.d.). However, the ranking does not represent the meaning of the actual score. Therefore, we adopted the *Adjective Rating Scale for SUS* that has a range from *Worst Imaginable* to *Best Imaginable* (Bangor et al., 2009). This type of scale has seven adjective ratings (Brooke, 2013). Table 9 presents the individual elderly participant's SUS score and adjective ranking of their feedback towards the usability of the Skiing Game.

Table 9. Individual's SUS Score

Participant ID	SUS score	Adjective rating[a]
4	95	Excellent
6	90	Excellent
10	85	Excellent
11	90	Excellent
12	87.5	Excellent
15	95	Excellent
16	92.5	Excellent
21	95	Excellent
1	80	Good
2	80	Good
5	77.5	Good
8	75	Good
9	77.5	Good
19	77.5	Good
20	77.5	Good
17	80	Good
3	62.5	OK
7	55	OK
13	65	OK
14	65	OK
18	70	OK
23	70	OK
24	67.5	OK
22	47.5	Poor

[a] Based on the SUS scores, none of the adjective ratings fell into the Worst Imaginable, Awful, or Best Imaginable adjective ratings.

As shown in Table 9, eight participants rated the game as *Excellent* (SUS score between 85 and 99). The percentage of the number of participants who rated the game Excellent is 33.33%. Eight participants rated the game as *Good* (SUS score between 73 and 84), which is 33.33% of the participants. The total number of participants who evaluated the game *OK* was seven (SUS score between 52 and 72), which is 29.17% of the participants. There was only one person who rated the game *Poor* (SUS score between 38 and 51), which is 4.17% of the participants. Figure 8 shows an overview of the SUS scores in adjective rating.

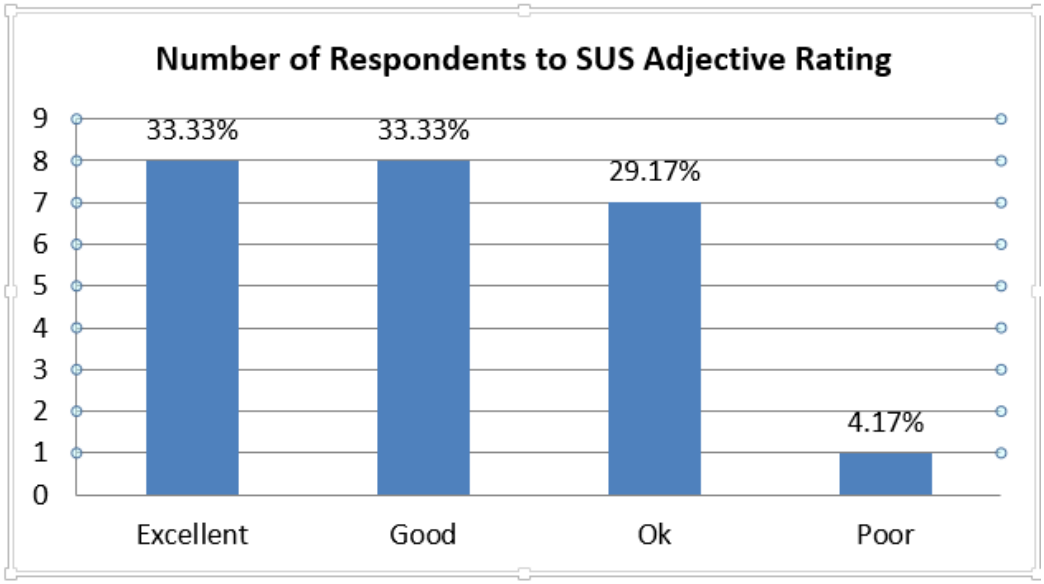

Figure 8. The overview of the SUS score in adjective rating.

According to the participants' responses to the post-gameplay questionnaires, there were 21 participants who agreed that playing digital games could be an effective and effortless way of exercising (Perceived Usefulness), whereas three out of 24 participants disagreed. With regard to the question of Perceived Ease-of-Use, all participants agreed that the game was easy to play. Furthermore, all participants agreed that they were able to play the game after receiving instructions. They also mentioned that the game instructions given in the game were adequate. There were six participants who mentioned that they were afraid of making mistakes during the gameplay, whereas 18 participants were not afraid of making mistakes. Table 10 shows the post-gameplay questionnaires and the participants' responses.

Table 10. Post-Gameplay Questionnaire

Post-gameplay questions		**No. of participants**	
		Agree	**Disagree**
Perceived Usefulness	Could playing digital games be an effective and effortless way of exercising?	21	3
Perceived Ease-of-Use	Was playing the game easy?	24	0
Gerontechnology Self-efficacy	Were you able to play the game after receiving instructions? Would the user instructions have been adequate?	24	0
Gerontechnology Anxiety	Were you afraid of making mistakes when playing the game?	6	18

Discussion

From the pre-gameplay interview, we observed that the Japanese elderly participants in this study were active in physical activities. They did physical exercises daily and weekly. In the pre-gameplay interview session, we found out that 12 participants did not have prior experience playing digital games, whereas the other 12 participants did have experience playing digital games.

According to the findings from the in-game GEQ questionnaires, we discovered that the participants had the highest positive experience with the Flow component, meaning that they were quite absorbed in the game. With regard to the Positive Affect, we observed that the participants were fairly positive about their experiences while they were playing the game. The Sensory and Imaginative Immersion component had the third largest score which means that the participants were fairly interested in the game during the gameplay. With regard to the Competence component, it can be said that the participants felt that they gained some achievements and skills in their gameplay to a certain extent. Regarding the component Challenge, participants reported that the game was moderately challenging, and they put effort into the gameplay. Conversely, the participants had noticeably lower Tension and Negative Affect scores while they were playing, which means that the participants did not feel frustrated and bored in their gameplay. Based on these findings, we can state that the participants were fairly engaged and interested in the game. Moreover, they felt challenged and put effort into the gameplay. More importantly, they felt content and good about the game. Therefore, we can say that the Japanese elderly participants in this study had fairly positive experiences while they were playing the Skiing Game.

Regarding the post-game GEQ questionnaires, we discovered that the participants had moderately positive experiences after they played the game. This outcome means that the participants were moderately satisfied and energized after the gameplay. In contrast, their negative experiences with the gameplay were noticeably low, which refers to the fact that the participants reported that they did not feel bad or discouraged after they played the game. Regarding the component Tiredness, we observed that the average score was very low, and we can say that the participants were not tired at all during the gameplay. However, this result can be linked to the fact that the gameplay session was relatively short, taking about 15 to 20 minutes to complete. They played a single game in the whole session, which might have led them to think that they did not get tired after playing the game. For the component Returning to Reality, which had a noticeably low average score, participants reported that they did not feel disoriented after they played the game. Based on these findings, we can generally say that the elderly participants were moderately positive about their experiences after playing the Skiing Game.

With respect to the correlation between the in-game and post-game GEQ components, there was a significant correlation between in-game Positive Affect and post-game Positive Experience. This correlation means that when the player had a more positive affection during the gameplay, he or she had a more positive experience after the gameplay. Based on the findings from both in-game and post-game GEQ questionnaire, we can say that the Japanese elderly participants' experiences in playing Skiing Game were fairly positive.

Concerning the usability of the game, although 12 out of 24 participants did not have prior experience in digital gameplay, their feedback towards the usability of the Skiing Game was noticeably positive: 16 out of 24 participants gave positive feedback (Excellent or Good). Some participants, 7 out of 24, commented that the game was OK. Notably, only one participant reported that the usability of the game was Poor. The participants who regularly played digital games gave the Skiing Game positive feedback (Excellent or Good). The participants who had previously reported negative impressions of digital games also gave relatively positive feedback for the game (Excellent, Good, and OK), except one participant who rated the game Poor. Based on the overall feedback from the participants, we can say that the usability of the Skiing Game for the Japanese elderly participants was fairly good and user-friendly.

With respect to the post-gameplay questionnaire, we observed that 21 out of 24 elderly participants mentioned that playing digital games could be an effective way of exercising for them, whereas the remaining participants did not recommend it. All participants commented that the game was easy to play, and they could easily follow the instructions. Of the 24 participants, 18 reported not feeling anxiety if they made a mistake during their gameplay, whereas the other six participants mentioned that they were nervous because they thought they'd make a mistake in their gameplay. Based on the findings from the post-gameplay questionnaire, most of the participants agreed that the Skiing Game was easy and an effective way to exercise.

According to the general feedback given by the participants, they mentioned that the game was interesting, easy to play, and they would like to play it again. They were also interested in playing digital game-based exercises regularly at the center. The only concern that the participants mentioned was that there was only one game and no option to choose to play. Moreover, the session was quite short. They recommended having more than one game to play and having it available for a longer time.

Based on the analysis of the participants' feedback towards the GEQ, SUS, and post-gameplay questionnaires, we highlight the following findings:

- The usability of the Skiing Game was fairly usable and user-friendly for the Japanese elderly participants.
- The participants' overall experience of playing the Skiing Game was fairly positive although most of them never played digital games before.
- Most of the participants agreed that the Skiing Game was easy and effective for them.

Based on the facts mentioned above, we can say that the Skiing Game is well-accepted by the Japanese elderly. The findings also highlight the potential of future game localization outside of Finland. However, further investigation on game localization and culturalization in a specific cultural group is still needed to improve the game.

The limitation of this study was that there was only the Skiing Game in this study. Furthermore, the duration of the usability testing was short, and the number of participants in this study was relatively small.

Usability Guidelines

We provide two kinds of guidelines for usability. First, we have recommendations for usability guidelines that we learned from the usability testing of the Skiing Game and the previous usability testing (Pyae et al., 2015a, 2015b; Pyae, Luimula, & Smed, 2016; Raitoharju et al., 2014). Second, we discuss usability issues that the participants encountered in this study.

Recommendations

The game context and content should be familiar and related to the elderly so that they can easily engage in the game. According to the findings from the previous usability testing, we found out that the elderly prefer game context and environment that are related to their personal lifestyles such as recreational activities and physical activities (Pyae et al., 2015a, 2015b; Raitoharju et al., 2014). Most elderly participants in this usability testing also advocated that they could relate to the context and contents of the Skiing Game, and thus, they could engage in the game.

We recommend that game actions in a particular game system should be natural and elder-friendly. The findings from the previous usability testing suggested that the elderly prefer natural game actions that they can easily perform such as bowling, tennis, and golf (Pyae et al., 2015a, 2015b; Pyae, Raitoharju, et al., 2016; Raitoharju et al., 2014). In this usability testing, the elderly participants advocated that the skiing-based game action was simple and easy. As a result, they could play and engage in the gameplay easily.

According to our previous usability testing, we observed that a simple and clear game interface reduces distractions for the elderly player (Pyae et al., 2015b). Furthermore, less but effective game contents can make the elderly more engaged in the game (Pyae et al., 2015b). Most elderly participants in this usability testing pointed out that the Skiing Game had an easy and simple game interface as well as uncluttered game contents. Therefore, they did not feel any

distraction while they were playing the game. Based on this point, we recommend that a simple and clear interface, as well as uncluttered game contents, should be taken into account when designing games for the elderly.

We observed in the previous usability testing that excessive audio feedback could make the elderly distracted from the gameplay (Pyae, Luimula, & Smed, 2016). In the Skiing Game, we used a simple and effective audio feedback so that the participants could not be distracted from the gameplay. Thus, there was no issue of audio feedback in the game. Based on this point, we recommend that game song and audio feedback should be simple but effective for the elderly.

Controller-free and motion-based interaction is easy for the elderly (Pyae, Raitoharju, et al., 2016). The findings from the previous usability testing also suggested that natural and motion-based interaction was an effective way for the elderly when they played digital games (Nakai et al., 2015, Pyae, Raitoharju, et al., 2016). In this usability testing, the Japanese elderly participants also pointed out that motion-based interaction to play the Skiing Game was effective and effortless. Based on these statements, we recommend that motion-based interaction is an effective way for the elderly to play a game.

Most of the elderly participants in this usability testing did not have prior experiences in playing digital games. Thus, we used simple and easy game actions in the Skiing Game such as the skiing action. Consequently, the elderly participants did not encounter major challenges in the gameplay, and they advocated that the game was easy to play. Therefore, we recommend that in designing games for novice elderly players, it is important to take into consideration that the game actions should be simple and effective.

Usability Issues

Visual cues are important for elderly players. In the Skiing Game, there were game obstacles for players to avoid while they were playing the game such as trees, stones, and fallen trunks on the skiing trail. We observed that some elderly participants did not notice these obstacles. As a result, it made them fall in the game, and some participants felt frustrated after he or she had encountered such a problem a few times. In this case, it would be a better game design if we displayed some visual cues for players to notice, as they were novice players.

The other usability issue is the repetition of a single action throughout the game. For instance, the participants played the game by moving their hands forward and backward to perform skiing actions. Some participants criticized that after they had played this single action for a certain time, they felt bored, and they would like to perform multiple actions so that the gameplay would be more interesting.

In Skiing Game, when a player hits an obstacle, the player falls down in the game. Some participants expressed their frustration when they experienced this for a number of times. Therefore, when we design a game for the elderly, it is important to design the game to reduce the frustration for elderly players when they consistently fail a particular game task.

According to the findings from the participants' general feedback, we found out that they preferred having a competitor or co-player option in the game to increase their engagement with the game. In the Skiing Game, there was not an option to play a competitor or co-player. In the future design of this game, including an option for a competitor or co-player would increase the appeal of the game for elderly players.

Lastly, we observed an important finding from this study that most of the elderly participants expressed their concern that they were afraid of falling while they were playing the game. Thus, it is worthwhile to question how we can design a game for the elderly to play alone while there is no one around, and show them how to prevent a fall.

Conclusion

In this study, we evaluated the Finnish Skiing Game with Japanese elderly participants to investigate the usability of the game and their user experiences in the gameplay. We conducted a usability test at the Sendai City Health Promotion Center in Japan with 24 Japanese elderly participants. We used the System Usability Scale (SUS) to investigate the participants' feedback towards the usability of the Skiing Game. We also used in-game and post-game GEQ questionnaires to understand the participants' user experiences during and after the gameplay. Based on the findings from the usability testing, we observed that the participants had fairly positive game experiences during and after the gameplay. The participants' feedback towards the usability of the Skiing Game is noticeably positive. Therefore, we can state that the Finnish Skiing Game is an easy and user-friendly physical exercise game for the Japanese elderly. Furthermore, they were interested in playing the game, and they would like to play it again. Most participants agreed that playing digital games are an easy and effective way of exercising.

Based on the findings mentioned above, we conclude that the Skiing Game designed for the Finnish elderly is usable and user-friendly for the Japanese elderly because of its simple game context, gameplay, and ease-of-use. From this study, we also recommend the game design improvements and usability guidelines discussed in this paper for our future game development as well as for other designers and practitioners in the related areas. As a future work, we will compare and contrast the findings between the Finnish and Japanese usability testing of the Skiing Game. Furthermore, we will conduct a similar study in other countries (e.g., Singapore).

Tips for Usability Practitioners

In this usability study, we observed the following game design recommendations and usability guidelines for elderly players that can be insightful and useful not only for our future game design and development but also for usability practitioners working in the areas of game usability and HCI:

- Take into consideration that the game interface, context, and contents should be simple and uncluttered so that elderly players are not distracted from the gameplay.
- Do not use excessive in-game instructions and unnecessary audio feedback which can cause too much distraction in playing a game designed for elderly players.
- Provide visual cues, which are important in the game especially for novice elderly players.
- Use controller-free and gesture-based interaction, which is effective for the elderly.
- Use natural and familiar game actions to make the game more engaging for elderly players.
- Provide options that reduce frustration in playing the game, even if they did not achieve a particular task. For example, provide positive, constructive, and encouraging feedback.
- Prevent and reduce the risk of falling, which is always important in designing games for the elderly's physical activity.

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Investigating the Finnish elderly people's user experiences in playing digital game-based skiing exercise: A usability study

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Elderly people's engagement in regular physical exercises is vital in old age. Digital games are promising to promote their engagement in physical exercises. The existing commercial games are not suitable for elderly people. More studies are required to undertake to investigate effective guidelines for designing digital games for elderly people. The main objective of this study is to investigate the Finnish elderly people's user experiences in playing a digital game-based exercise called 'The Skiing Game'. Furthermore, we aimed at studying the difference between elderly people's attitude towards physical and digital game-based exercises. Lastly, we intended to investigate if digital games can be an alternative solution for elderly people to exercise. We conducted a usability evaluation of the game with 21 Finnish elderly participants in Finland. The findings show that the Skiing game is a simple, easy, and user-friendly game for the elderly participants. Their in-game and post-game experiences were moderately positive. Their attitudes towards digital games were moderately negative. However, their attitudes have changed more positively after the gameplay. They also showed their interests in the game, and recommend that digital games can be an effective way of exercising for them. Through participants' observation, we recommend a number of usability and game guidelines for designing digital games for elderly people. The findings from this study can help researchers and practitioners in the related areas to gain insightful knowledge about adopting and utilizing digital games for promoting elderly people's physical exercise activities.

Keywords: usability, user experiences, physical exercise game, gamification

According to the American Psychological Association[1], elderly people experience natural and normal age-related changes, which may impact their quality of life. Physical decline and functional incapacity are common age-related changes for elderly people[2]. Manini[3] highlights that the ageing population will result in higher rates of physical disabilities that result from the ageing process and chronic diseases[3]. Physical health declines with age, and it is associated with the likelihood of disability[4].

The World Health Organization (WHO)[5] suggests that being engaged in physical activities can improve elderly people's physical health, functional capability, and cognitive skills. Physical activities include regular exercises (e.g. balance, stretching, and strengthening), activities of daily living (e.g. household chores), leisure activities (e.g. gardening and walking), and playing games (e.g. bowling). Physical exercise is an effective non-pharmaceutical intervention for elderly people to prevent from suffering cognitive decline and neurodegenerative disease (e.g. Alzheimer's disease)[6]. The positive effects of physical exercises on elderly people are not only prevention of age-related diseases, but also an improvement in the quality of life[7].

Participation in regular physical exercises can decline when a person becomes aged[8]. An ageing process can reduce the physical fitness of an elderly person, including strength, endurance, agility, balance, and flexibility. Consequently, he or she may encounter difficulties in doing activities of daily living, and become reliance on others

such as family members and caregivers. Furthermore, physical decline in old age can have negative impacts on an elderly person's well-being and quality of life such as social role changes, disengagement in social activities, and depression[9].

In recent years, people have used modern technologies to promote elderly people's physical activities such as ambient assisted living for ageing[10] and robots for frail elderly people's rehabilitation[11]. Among them, digital games have the potential to improve elderly people's physical abilities[12-14]. Different terms are used to define the concept of digital game-based physical exercises for elderly people, including serious games for healthcare[15], exergames[16], and gamification for healthcare[17]. To date, there have been a number of studies that investigated the usability and usefulness of existing games and technologies for elderly people's physical healthcare such as Nintendo Wii Fitness games[18,19], Kinect for Xbox Fitness games[20,21], and PlayStation PlayMove Fitness games[22].

IJsselsteijn, Nap, & de Kort[23] highlighted that the digital games market for elderly people is significantly large because the majority of game developers primarily focus on the young users. Furthermore, commercial games do not meet the needs of the elderly population. Elderly users encounter more usability problems in playing digital games, compared with the younger users due to their limited functional abilities and lack of prior experiences in gameplay[23].

Although there are an increasing number of studies on user experiences and usability guidelines for younger users in various contexts, little is known for an elderly population in digital games[24]. To date, there have been some promising studies for user experiences and the usability of digital games for elderly people[25,26]. Nevertheless, this is an on-going work, and it is important to investigate more widely in this specific area so that we can design more usable and useful digital games for elderly people's physical well-being.

In this study, we aim at understanding the usability of the Skiing Game for elderly people as well elderly participants' user experiences in the gameplay. Furthermore, we are interested in differences between elderly participants' attitudes towards traditional physical exercises and digital game-based exercises. In addition, we aim at investigating if digital game-based exercises can be an alternative solution for their physical exercise activities. We conducted a usability study with 21 Finnish elderly participants in Finland and collected their feedback towards the game, user experiences, and attitudes. We also observed their gameplay, interaction experiences, and challenges. Then, we analyzed and reported the findings, followed by usability and game design recommendations. The findings in this study can be useful and insightful for our future works as well as for other researchers and practitioners working in the related areas.

Background

Gamified Solutions in Healthcare (GSH)

GSH is a research project, which aims at promoting elderly people's quality of life through digital game-based solutions. This includes active ageing, cost-effective healthcare solutions, socialization, and safety for elderly people[27]. In this study, we only emphasize the 'Rehabilitation' services that aim at providing digital game-based exercises for elderly people to improve their engagement and motivation in a regular physical exercise activity[28]. Furthermore, it aims at providing digital game-based rehabilitative exercises for elderly people with physical disabilities (e.g. stroke patients).

Before we implemented rehabilitation services for elderly people, we conducted a few preliminary studies to understand the requirements of elderly people for their physical activities and exercises. We visited elderly service homes in Finland and observed their needs in daily activities, including physical exercises, social connection, and recreation. We also studied the usability and usefulness of existing digital games and technologies for elderly people. Then, we conducted a number of usability testing of commercial digital games with the Finnish elderly participants in Turku, Finland. We also evaluated the usability games developed by Puuha Group Finland and Turku Game Lab.

The preliminary findings were reported in the previous publications, including a literature review on digital games for elderly[27], understanding motivational factors for elderly people[28,29], a review of existing commercial games[27,30], a usability testing of commercial games, the SportWall game by Puuha Group Finland, and interaction devices for elderly people[29,31,32]. The findings from the preliminary studies are useful and insightful for our game design, development, and future usability testing of digital games for GSH project.

Based on the findings from the preliminary studies, we designed and developed a digital physical exercise game called the 'Skiing Game'[33]. Next, we evaluated this game with the Finnish elderly participants in Finland to understand the usability of the game and user experiences. In this paper, we report and discuss the findings from the usability testing of the Skiing game with the Finnish elderly participants. The main objectives of the usability testing are:

(i) To investigate the Finnish elderly people's feedback towards the usability of the Skiing game.
(ii) To explore the Finnish elderly people's user experiences during and after the gameplay, and
(iii) To understand their attitudes towards physical exercises and digital-game based exercise, as well as their differences.
(iv) To examine if digital games can be an alternative solution for promoting elderly people's participation in physical exercise activities, and
(v) To identify usability challenges and guidelines for elderly people in playing digital game-based exercises.

Research gap

As digital games have been used for promoting elderly people's physical well-being in terms of physical exercises and rehabilitation, researchers, especially in the area of Human-Computer Interaction (HCI), have become interested in understanding the usability and game design guidelines of digital games for an ageing population. To date, there have been a number of studies in the literature that investigated and proposed usability and game design guidelines for designing digital games for elderly people. For instance, IJsselsteijn et al.[23] reviewed and discussed digital game design to explore design opportunities to create digital games with engaging content and friendly interface that elderly users can easily and pleasurably use. Gerling, et al.[25] evaluated full-body motion-based games for elderly people, and they proposed seven usability guidelines for designing full-body interaction games for them. Planinc et al.[34] conducted a usability study of digital game-based exercises or exergames to investigate their appropriateness for elderly people.

Although digital games have shown the potential for elderly people's physical well-being, this research area has still many challenges to be addressed in terms of game design, interaction design, usability, and usefulness. IJsselsteijn et al.[23] pointed out that Digital games are promising as a tool to enhance elderly people's mental and physical workout; however, most digital games in the market are targeted at the younger players. Furthermore, Gerling et al.[25] highlighted that the contents of the commercial games are generally not suitable for elderly people.

According to Nap, Kort, and IJsselsteijn[35], senior gamers or elderly players do exist, but compared with the number of younger players, they are still a small audience in this context. Thus, it is important to know more clearly about elderly players' problems and challenges in playing digital games. It is still state-of-the-art, and unclear what motivates elderly players to engage in digital gameplay, what type of games they prefer to play, what problems they encounter with game interfaces and usability, and what their perceptions and attitudes towards digital gameplay are[35]. Marin, Lawrence, Navarro, and Sax[36] also pointed out that more studies should be undertaken to develop reliable guidelines, which would help game designers and usability practitioner to create more useful and usable games, especially for elderly people. Nawaz et al.[37] also highlighted that future studies should be carried out to investigate quantifiable results and more insights about the usability of digital games for elderly people.

Usability

In the literature, there are a number of definitions of the term 'Usability' that are different from one another. For instance, ISO/IEC 9126-1 defines that the capability of a particular software product to be understood, learned, used, and attractive to users, when used under specified conditions[38,40]. ISO9241-11 also defines usability as the extent to which a particular product can be used by specific user groups to achieve specific goals with effectiveness, efficient, and satisfaction in a specific context of use[39,40]. IEEE also defines that the ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a particular system or component[40]. Based on the different definitions, we learn that the term usability contains common components such as the ease-of-use, efficiency, and effectiveness of a system. Furthermore, it is associated with users' learnability and satisfaction in using a system.

According to Nielsen, usability is defined as a quality attribute that assesses the ease-of-use of a particular system's user interfaces[41]. The author also states that a key element of 'usability' is utility that refers to the design's functionality that can fulfill what users need in using a particular system. The author also defines the five quality components of usability, including learnability, efficient, memorability, errors, and satisfaction. Learnability refers to how easy a particular system is for a first-time user and efficiency means how quickly a user can accomplish a task in using a particular system. Memorability refers to how easily a user can reestablish proficiency in using a particular system after returning from a long period of not using it. Errors mean how many errors a user makes in using a particular system and how easily and quickly they can recover from it. Finally, satisfaction means how pleasant a particular system is for a user to use the design. In this study, we are interested in the usability of the Skiing game for elderly people. Specifically, we aim at investigating the ease-of-use of the game for elderly people, as well as the learnability of it. We are also interested in elderly people's user experiences in playing the game in

terms of their positive and negative experiences before and after the gameplay. Through participants' observation in the usability testing, we aim at identifying usability challenges encountered by elderly people, as well as proposing usability guidelines and game design recommendations.

Skiing game

We designed and developed the Skiing game based on the following findings from the preliminary studies[27,28,31]. In our previous usability studies, we found that elderly people preferred game context and background that are familiar to them and close to real-life environments and activities. For instance, they like to play card games, sport-based games, and recreational activities (e.g. dancing and singing games). Furthermore, they like natural and user-friendly game play and actions, which can be familiar to them[30]. As an example, they like tennis, bowling, and dancing games. According to the findings from the previous studies[32], we observed that simple and easy interaction techniques are effective for elderly people while playing a digital game. They prefer controller-free natural interaction to play digital games (e.g. a motion detection device). The elderly participants in the previous usability tests recommended simple and easy in-game instructions to follow. Furthermore, they suggested that simple and clear feedback is important to play a game more easily.

In the Skiing game, we chose snowy mountains and a forest as the game context and background because Skiing as a physical activity is popular and familiar to most Finnish elderly people. The gameplay is simply designed based on an action of steering a pair of skiing poles. A player needs to move both hands forward and backward to ski in the game. He or she needs to move body either left or right to avoid obstacles in the game. In this game, we adopted a double pole skiing technique. Generally, this game is relatively easy and is a familiar exercise activity to the most Finnish elderly who had previous experiences with cross-country skiing.

To design and develop the Skiing game, we use the Unity 3D game engine. For the game interaction, we used a webcam with Extreme Reality (XTR3D) Technology to detect a player's upper-limb movements. Extreme Reality supports a software-based motion analysis. It can be integrated with any computing device by using a traditional web-camera to track a player's movements[42]. XTR3D technology includes a motion detection engine, which captures the 3D position (X, Y, and Z) of a player's skeletal position just in front of the camera in every frame. It creates a live 3D model of a player, which is analyzed by a software to recognize the gestures from the skeletal positioning of a player.

Methods

To evaluate the usability of the Skiing game, we conducted a usability test with the Finnish elderly participants at an elderly service home called 'Ruusuvalkama', which provides physical, social, and health services for elderly people in Finland.

Elderly participant recruitment

The recruitment of the Finnish elderly participants was undertaken by the staffs from the elderly service home. They advertised participant recruitment at their place, and if a particular elderly person is interested in taking part in this study, they assessed if he or she is fit to participate. There are a number of selection criteria in this recruitment. Specifically, an elderly person should be 60 years and above. His or her health condition should be stable. Furthermore, he or she needs to be physically and mentally capable, with no neurological or cognitive deficits. He or she can resist for playing a game for at least 15 minutes in a standing position. They also should have a capability of independent standing and walking 10 meters. The staff from the elderly services home selected the individual elderly participant carefully to meet the needs of our study. Once an individual participant agreed to take part in this study, we requested his or her consent.

Usability test design and procedure

We recruited a total of 21 Finnish elderly participants in this study. The average age of the participants is 76 years old. We conducted two-day usability testing at the elderly service home. On the day-one, 12 elderly people participated, and the remaining 9 participants joined on the day-two. Three researchers conducted the usability testing and the Finnish language was used to communicate the elderly participants. At the station one (room 1), one researcher conducted the pre-study session that includes questionnaires and interview questions investigating the participants' demographic information, their physical exercise activities, and their attitudes towards physical exercises. We also requested the individual's consent to be involved in this study. The pre-study session took about 5 to 10 minutes.

The second researcher took in-charge of the Station two (room 2) where the participants played the Skiing Game. The researcher guided the participants on how to play the game and monitored them to minimize their potential physical risks. The duration of the gameplay for the individual participant took about 20 minutes. In the station three (room 3), the third researcher asked the participants to complete the post-gameplay

questionnaires and interview. These include in-game and post-game GEQ questionnaires, SUS questionnaire, elderly participants' attitudes towards digital game-based exercises, and post-study interview questions. We observed the participants' behavior, user experiences, and responses towards the game by using a video recorder and note-taking. The detailed procedures of the usability study are mentioned in *Table 1*.

Table 1. Skiing Game usability testing design and procedures

Activity	Duration	Station
Introduction to the usability testing Pre-study interview	10 min	1
Game Tutorial guided by a researcher Skiing Game played by elderly participants Break-time	20 min 5 min	2
Post-study questionnaire Total	10 min 45 min	3

Questionnaires

Attitudes towards physical exercise questionnaire

In this study, before the elderly participants played the Skiing game, we investigated their attitudes towards physical exercise in their old age. Furthermore, we also investigated their attitudes towards digital game-based exercise after they have played the game. To investigate their attitudes, we created questionnaire based on the attitudes of older adults toward physical activity and exercise developed by Terry et al.[43]. The questionnaire items are provided in the data analysis section.

System Usability Scale (SUS)

To investigate participants' feedback towards the usability of the Skiing Game, we used SUS, which is easy and simple to understand for elderly people. It includes a total of 10 items that gives the subjective assessments of the usability of a particular system[44]. SUS is based on the 5-point Likert scale from Strongly disagree (1) to Strongly agree (5). It can be used to assess a wide range of products and services that include software and hardware systems, mobile devices, applications, and websites[45].

This scale can be also used for a small sample size, and it is easy to apply to participants. According to Sauro[46], while SUS is intended to measure perceived ease-of-use of a system, it can also provide not only usability but also learnability dimensions. Brooke[47] indicated that SUS is technology-neutral, and it has been continuously applied in many studies as technology has become more advanced over the past years without reinventing the questionnaires. SUS is an effective tool for measuring the usability of a system or product, and it provides a score from 0 to 100, which is easy to understand for participants[48]. The authors also advocated that it is a highly robust and flexible tool for usability practitioners[49]. In our study, we modified it to a game system and its usability, whereas the original version of SUS refers to a particular system. *Table 2* shows the revised version of the SUS questionnaires that are used in our usability testing of the Skiing Game.

Table 2. System Usability Scale (SUS) modified for this study

Questionnaires
1. I think that I would like to play this game frequently.
2. I found this game unnecessarily complex.
3. I thought this game was easy to play.
4. I think that I would need the support of a technical person to be able to play this game.
5. I found the various functions in this game were well integrated.
6. I thought there was too much inconsistency in this game.
7. I would imagine that most people would learn to play this game very quickly.
8. I found this game very cumbersome to play.
9. I felt very confident playing this game.
10. I needed to learn a lot of things before I could get going with this game.

Game Experience Questionnaires (GEQ)

In this study, we used GEQ to investigate participants' experiences during and after the gameplay. We used two GEQ modules: in-game and post-game to assess players' experiences in the game[50]. The GEQ in-game module is utilized to explore a player's game experience during a game-play session. It has seven components including Sensory and imaginative immersion, Flow, Competence, Positive affect, Negative affect, Tension, and Challenge[51,52]. According to Norman[45], GEQ is a reasonable and applicable questionnaire in exploring a player's experiences with a particular game system. The author also advocated that it has been widely and successfully used in many studies internationally[53].

Johnson, Wyeth, Sweetser, and Gardner[54] mentioned that 'Competence', 'Tension', 'Negative affect', and 'Positive affect' can be easily understood by their titles. 'Competence' refers to a player's skills in playing a game (e.g. I felt skillful). The component 'Tension' is about a player's level of frustration in playing a game (e.g. I feel frustrated). 'Positive affect' refers to a player's positive affection (e.g. I felt good), whereas 'Negative affect' means that a player feels negative while playing the game (e.g. I felt bored). The component 'Challenge' refers to a player's effort, challenge, and pressure in the game (e.g. I had to put a lot of effort into it). The component 'Sensory and imaginative immersion' refers to how interested a player is in a game's story (e.g. I was interested in the game's story). Finally, the component 'Flow'

is about how engrossed a player feels while playing a game (e.g. I felt completely absorbed). All GEQ in-game components and response options from the questionnaires are provided in *Table 3*.

Table 3. In-Game GEQ components and response options from the questionnaires

In-game GEQ components	Response option
Sensory and imaginative immersion	I was interested in the game's story. I found it impressive.
Flow	I forgot everything around me. I felt completely absorbed.
Competence	I felt successful. I felt skillful.
Positive affect	I felt content. I felt good.
Negative affect	I felt bored. I found it tiresome.
Tension	I felt frustrated. I feel irritable.
Challenge	I felt challenged. I had to put a lot of effort into it.

We also used the GEQ post-game questionnaire to assess how players felt after playing a particular game[55]. It has four components including 'Positive experience', 'Negative experience', 'Tiredness', and 'Returning to reality'. The 'Positive experience' component refers to a player's positive experiences after he or she has played a game such as satisfaction, victory, and power (e.g. I felt satisfied). The 'Negative experience' component is about a player's bad experiences after playing a particular game (e.g. I felt bad). The component 'Tiredness' refers to a player's exhaustion in playing a game (e.g. I felt exhausted). The 'Returning to reality' component is about a player's disorientation after he or she has played a game (e.g. I found it hard to get back to reality). For both GEQ in-game and post-game questionnaires, we used a 5-point Likert scale from Not at all (0) to Extremely (4). All GEQ post-game components and response options from the questionnaires are stated in *Table 4*.

Post-Gameplay interview questions

We implemented the post-gameplay interview questions, which were adapted from the Senior Technology Acceptance & Adoption Model[56]. There are four questionnaire items to investigate the elderly participants' perceptions after they have played a game:

(i) 'Perceived Usefulness' was used to understand the effectiveness and usefulness of playing digital games.

(ii) 'Perceived Ease-of-Use' was used to find out if playing the Skiing Game was easy for them.

(iii) 'Gerontechnology Self-Efficacy' was used to find out if the player could easily play after receiving the game instructions and to determine if the game instructions were adequate.

(iv) 'Gerontechnology Anxiety' was used to investigate if the player was afraid of making mistakes during the gameplay.

Figure 1. Skiing Game usability testing

Participants observation

In this usability testing, we observed the elderly participants' behavior, expression, emotions, and feedback. We used a video recorder to capture elderly participants' interaction experiences and the usability problems encountered by them. We also applied note taking technique in the situation when the individual elderly participant disliked to be recorded. *Figure 1* shows a picture being taken during their gameplay.

Results

In this section, we report the findings from the analysis of pre-study interview questions, SUS, In-game and Post-game GEQ, and post-study interview questions.

Pre-study interview

From the pre-study interview, we observed that 20 out of 21 elderly participants do regular exercises such as stretching, balance training, walking, cycling, and jogging. 11 out of 20 elderly participants perform physical exercises daily for 1-2 hours, whereas 9 participants exercise weekly for at least 2 hours. The elderly participants who exercise regularly stated that participation in regular physical exercises are important in old age, and they enjoy doing it. Only one elderly participant who is 85 years old had already stopped doing exercises, claiming that she was too old to do exercises.

Regarding prior experiences in playing digital games, 18 out of 21 elderly participants did not play digital games before. 10 out of 18 elderly participants mentioned that they were not interested in digital games while two elderly participants

Table 4. Post-Game GEQ components and response options from the questionnaires

Post-game GEQ components	Response option
Positive experience	I felt revived. It felt like a victory. I felt energized. I felt satisfied. I felt powerful. I felt proud.
Negative experience	I felt bad. I felt guilty. I found it a waste of time. I felt that I could have done more useful things. I felt regret. I felt ashamed.
Tiredness	I felt exhausted. I felt weary.
Returning to reality	I found it hard to get back to reality. I felt disoriented. I had a sense that I had returned from a journey.

claimed that it was a waste of time and the other two did not provide reasons. Two elderly participants revealed that they did not have a device to play digital games, whereas one participant did not like it. The last participant mentioned that digital games are meant for the younger people.
In this study, we observed that there were only three elderly participants who have played digital games before. They played Bejeweled, Sudoku, Solitaire, Chess, and Mahjong games. They used computer and mobile phones to play digital games. They commented that playing digital games is entertaining for them, as well as a good way to waste time in old age. They also recommended that digital games can improve their cognitive abilities and memory.

Attitudes towards physical exercises

Before the elderly participants played the game, we investigated their attitudes towards physical exercise. According to the findings from the analysis of data, we observed that all participants recommended that physical exercise is essential to good health (M=5.0). They believed that physical exercises can help to work of emotional tension and anxieties (M=4.9). All elderly participants advocated that physical exercises are important for maintaining health (M=5.0), and it is beneficial to the human body (M=5.0). Lastly, they recommended that regular physical exercise can make one feel better (M=5.0).

According to the following *Table 5*, we found that all elderly participants strongly agreed that participation in physical exercise is essential to good health. We also observed that 85.71% of participants strongly agreed on the fact that physical exercises can help them to work of tension and anxieties while 14.29% just agreed on it. Furthermore, all participants strongly advocated that doing physical exercises is important for a person to gain and maintain all-around health. All elderly participants also strongly agreed that it can be beneficial to the human body. Lastly, we observed that 95.24% of elderly participants strongly agreed that doing regular physical exercises can make them feel better and the other 4.76% just agreed on it.

SUS

After the elderly participants had played the game, they provided their feedback towards the usability of the Skiing game by responding to the SUS questionnaire. We analyzed their responses based on the original method by Brooke[44]. According to this method, each participant was given a score, which ranges from 0 to 100. Basically, a score lower than 68 was defined as 'Below Average', whereas greater than 68 is 'Above Average'[45,46]. As this score does not provide a specific meaning, we adopted the Adjective Rating Scale for SUS implemented by Bangor et al.[48]. This Adjective Rating Scale has seven adjective scales, including 'Worst imaginable', 'Awful', 'Poor', 'Ok', 'Good', 'Excellent', and 'Best imaginable'. *Table 6* shows the individual's SUS score and adjective scale towards the usability of the Skiing game. The following *Figure 2* shows the graphical representation of SUS scores and Adjective ranking.

According to *Table 7*, we observed that there is only one participant (4.76%) who rated the game 'Best imaginable'. Noticeably, there are a total of

Table 5. Elderly participants' attitudes towards physical exercise in 5-Point Likert scales

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Q1. Physical exercise is essential to good health.	0.00%	0.00%	0.00%	0.00%	100.00%
Q2. Physical exercise helps to work of emotional tension and anxieties.	0.00%	0.00%	0.00%	14.29%	85.71%
Q3. Physical exercise is important in helping a person to gain and maintain all-around health.	0.00%	0.00%	0.00%	0.00%	100.00%
Q4. Physical exercise is beneficial to the human body.	0.00%	0.00%	0.00%	0.00%	100.00%
Q5. Regular physical exercise makes one feel better.	0.00%	0.00%	0.00%	4.76%	95.24%

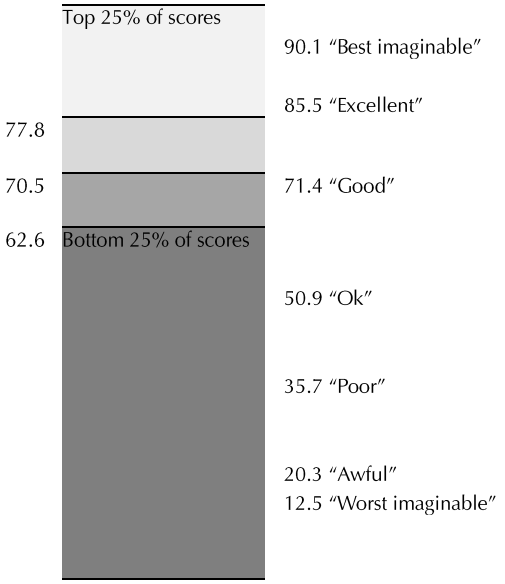

Figure 2. SUS scores and adjective rankings[57]

nine participants (42.86%) who rated the game 'Excellent'. Six elderly participants (28.57%) rated the game 'Good' while two participants (9.52%) for 'OK' and 'Poor' individually. Lastly, there is one participant (4.76%) who commented that the game was 'Worst imaginable'. For acceptability ranges of SUS, we observed that 16 out of 21 participants commented that the usability of the game was within the acceptable range while 2 participants rated as marginal. In contrast, 3 out of 21 participants revealed that the game was not acceptable.

We also analyzed the individual SUS item in 5-point Likert scale (from Strongly disagree to Strongly agree) (*Table 7*). We observed that more than 60% of participants responded that they would like to play this game frequently. We also found that more than 70% of them strongly disagreed that the game was unnecessarily complex, while 14.29% just disagreed. Furthermore, more than 60% of participants strongly agreed that the game was easy to play. Regarding the support from a technical person, 57.14% of participants commented that they did not need any support, whereas 19.5% commented that they needed support from a technical person. 57.14% of participants strongly agreed that the game was well-integrated with various functions, while 28.57% just agreed and 4.76% were neutral. Noticeably, more than 80% of total participants strongly disagreed that the game had inconsistencies. We observed that 76.19% of participants strongly agreed and 14.29% just agreed that the game was easy to learn. With regard to the gameplay, more than 75% of participants strongly disagreed that the game was cumbersome to play. Regarding the participants' confidence in playing the game, approximately 52% strongly agreed, whereas 33.34% strongly disagreed. Lastly, more than 50% of elderly participants strongly disagreed that they needed to learn a lot of things before playing the game.

In-game GEQ

We report the findings from the analysis of in-game GEQ questionnaire responded by the elderly participants. The analysis was conducted based on the calculation method by IJsselsteijn et al.[50]. According to *Table 8*, we observed that 'Positive affect' component had the highest score (M= 3.0). For this component, we observed that the participants felt content in the gameplay (M=2.8) and they felt good to play it (M=3.3). The component 'Flow' has the second highest score (M= 2.6). For this component, the participants responded that they forgot everything around them while playing the game (M= 2.3) and were moderately absorbed in the gameplay (M=2.9). The components 'Sensory and Imaginative' and 'Competence' had the same score (M= 2.3). For 'Sensory and imaginative', although they were fairly interested in the gameplay (M= 2.5), they were less impressive with the game (M=1.5). For competence, they felt successful (M=2.6) and skillful (M=0.9). Regarding the component 'Challenge', it had the second lowest score (M= 1.2). For this component, the game was less challenging for them (M= 1.8) and they did not put effort into the gameplay (M=1.1). The components 'Tension' and 'Negative affect' had the least score (M= 0.1) individually. For the component 'Tension', they were less frustrated (M=0.1) and irritated (M=0.4) respectively. Lastly, for the component 'Negative affect', the participants were not bored in the gameplay (M= 0) and they found the gameplay tiresome (M=0.3).

Table 6. SUS scores and adjective scales

SUS adjective rating (Score range)	Number of participants	Acceptability ranges	Percentage	Mean	SD
Best imaginable (90-100)	1	Acceptable	4.76%	100	0
Excellent (80-89)	9	Acceptable	42.86%	88.9	4.7
Good (63-79)	6	Acceptable	28.57%	78.3	5
OK (47-62)	2	Marginal	9.52%	68.8	1.8
Poor (25-46)	2	Not acceptable	9.52%	49	1.8
Worst imaginable (0-24)	1	Not acceptable	4.76%	17.5	0

Table 7. SUS scores in 5-point Likert scale

SUS Items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Q1. I think that I would like to play this game frequently.	14.29%	9.52%	16.67%	42.86%	23.81%
Q2. I found this game unnecessarily complex.	71.43%	14.29%	4.76%	4.76%	4.76%
Q3. I thought this game was easy to play.	4.76%	0.00%	14.29%	14.29%	66.67%
Q4. I think that I would need the support of a technical person to be able to play this game.	57.14%	14.29%	4.76%	4.76%	19.05%
Q5. I found the various functions in this game were well-integrated.	0.00%	9.52%	4.76%	28.57%	57.14%
Q6. I thought there was too much inconsistency in this game.	71.43%	23.81%	42.86%	4.76%	0.00%
Q7. I would imagine that most people would learn to play this game very quickly.	0.00%	0.00%	9.52%	14.29%	76.19%
Q8. I found this game very cumbersome to play.	52.38%	23.81%	0.00%	9.52%	14.29%
Q9. I felt very confident playing this game.	14.29%	19.05%	14.29%	19.05%	33.33%
Q10. I needed to learn a lot of things before I could get going with this game.	47.62%	23.81%	4.76%	9.52%	14.29%

According to the findings from the analysis of In-game GEQ individual items, we observed that most of the elderly participants (more than 60%) agreed that they felt content to play the game and 76% felt good in the gameplay. Regarding the flow in the game, 33.33% of participants strongly agreed that they forgot everything around them while 23.81% strongly disagreed. Furthermore, 47.62% strongly agreed and 23.81% just agreed on it. We also found that 42.86% strongly agreed that they were interested in the game, whereas 23.81 did not. Furthermore, 38.10% strongly agreed that the game was impressive, followed by 14.29% who strongly agreed on it. Regarding competence, 24.86% just agreed that they felt successful while more than 30% agreed that they were skillful, whereas more than 20% strongly disagreed and 33.33% were neutral. With regard to the component challenge, only 38.10% just agreed that they felt challenged, whereas more than 30% did not agree and 19.05% was neutral. Noticeably, more than 50% strongly disagreed they put effort into the gameplay. In addition, we observed that approximately 90% strongly did not agree that they were frustrated in the gameplay while all participants (100%) also strongly disagreed that they felt irritable. Lastly, all participants (100%) were not bored to play the game while more than 80% strongly disagreed that the game was tiresome.

Post-game GEQ

After the elderly participants had played the game, we asked their post-game experiences by using post-game GEQ questionnaire. Based on the findings from the analysis (*Table 9*), we observed that the participants had an average positive experience (M=2.0). We found that they were moderately satisfied with the game (M=2.5), followed by a victory (M=2.1) and being proud (M=2.1) respectively. Furthermore, the participants felt revived (M=2.0), energized (M=1.9), and powerful (M=1.6) respectively. In contrast, we observed that the elderly participants had almost no negative experiences (M= 0.1). They had a very low score in guilty (M=0.1) waste of time (M=0.2), while they did not feel bad, regret, and ashamed (M=0). Furthermore, we found that their tiredness had a noticeably low score (M=0.1). They felt weary (M= 0.1) and had no exhaustion (M=0). Lastly, regarding returning to reality, we observed that they also had a low score (M=0), including getting back to reality (M=0.2) and disorientation (M=0.9). We also found that they had a low score in returning from a journey (M=1.3).

We also analyzed the Post-game GEQ items in 5-point Likert scale (*Table 10*). We found that more than 30% elderly participants were neutral for their satisfaction and feeling powerful in the gameplay. We also observed that more than 35% of participants disagreed that they felt energized to play the game. In contrast, 28.57% of elderly participants agreed that they felt like a victory in the gameplay while the same percentage of participants remained neutral for being revived in the game. For being proud to play the game, 28.57% of participants strongly disagreed, whereas other 28.57% strongly agreed on it. Regarding the negative experiences, more than 80% of the participants strongly disagreed that they experienced negatively to play the game. Furthermore, concerning tiredness of the participants, more than 80% strongly disagreed that they had such experience. Lastly, 90% of the participants strongly disagreed that they found it hard to go back to

Table 8. In-game GEQ scores in 5- point Likert scale

GEQ Items	Mean	Standard Deviation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Positive affect	3	0.9					
I felt content	2.8	1.2	9.52%	0.00%	23.81%	33.33%	33.33%
I felt good	3.3	1.1	4.76%	0.00%	19.05%	14.29%	61.90%
Flow	2.6	1.2					
I forgot everything around me	2.3	1.6	23.81%	9.52%	14.29%	19.05%	33.33%
I felt completely absorbed	2.9	1.3	4.76%	19.05%	4.76%	23.81%	47.62%
Sensory and imaginative	2.3	1.3					
I was interested in the game's story	2.5	2.1	23.81%	0.00%	4.76%	42.86%	28.57%
I found it impressive	1.5	1.3	19.05%	14.29%	14.29%	38.10%	14.29%
Competence	2.3	1					
I felt successful	2.6	1.9	4.76%	4.76%	33.33%	42.86%	14.29%
I felt skillful	0.9	1.2	19.05%	9.52%	33.33%	33.33%	4.76%
Challenge	1.2	0.7					
I felt challenged	1.8	0.7	14.29%	28.57%	19.05%	38.10%	0.00%
I had to put a lot of effort into it	1.1	0.9	52.38%	33.33%	9.52%	4.76%	0.00%
Tension	0.1	0.2					
I felt frustrated	0.1	0	90.48%	4.76%	4.76%	0.00%	0.00%
I felt irritable	0.4	0	100.00%	0.00%	0.00%	0.00%	0.00%
Negative affect	0.1	0.3					
I felt bored	0	0	100.00%	0.00%	0.00%	0.00%	0.00%
I found it tiresome	0.3	0.8	80.95%	9.52%	4.76%	4.76%	0.00%

Table 9. Post-game GEQ scores in 5-point Likert scale

GEQ Items	Mean	Standard Deviation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Positive experience	2	0.3					
I felt revived	2	1.4	23.81%	9.52%	28.57%	19.05%	19.05%
It felt like a victory	2.1	1.3	14.29%	19.05%	23.81%	28.57%	14.29%
I felt energised	1.9	1.1	4.76%	38.10%	33.33%	9.52%	14.29%
I felt satisfied	2.5	1.2	4.76%	14.29%	33.33%	23.81%	23.81%
I felt powerful	1.6	1.2	23.81%	19.05%	38.10%	9.52%	9.52%
I felt proud	2.1	1.6	28.57%	9.52%	9.52%	23.81%	28.57%
Negative experience	0.1	0.1					
I felt bad	0	0	95.24%	4.76%	0.00%	0.00%	0.00%
I felt guilty	0.1	0.5	85.71%	9.52%	4.76%	0.00%	0.00%
I found it a waste of time	0.1	0.4	90.48%	4.76%	4.76%	0.00%	0.00%
I felt that I could have done more useful things	0.2	0.6	80.95%	9.52%	9.52%	0.00%	0.00%
I felt regret	0	0	100.00%	0.00%	0.00%	0.00%	0.00%
I felt ashamed	0	0	95.24%	4.76%	0.00%	0.00%	0.00%
Tiredness	0.1	0.1					
I felt exhausted	0	0	95.24%	0.00%	4.76%	0.00%	0.00%
I felt weary	0.1	0.4	80.95%	19.05%	0.00%	0.00%	0.00%
Returning to reality	0.8	0.5					
I found it hard to get back to reality	0.2	0.8	90.48%	4.76%	0.00%	0.00%	4.76%
I felt disoriented	0.9	1	42.86%	38.10%	14.29%	0.00%	4.76%
I had a sense that I had returned from a journey	1.3	1.4	38.10%	33.33%	4.76%	9.52%	14.29%

reality while approximately 42% of them felt disoriented and 38% felt that they had returned from a journey after the gameplay.

Correlation between In-game and Post-game GEQ variables

We analyzed the correlation between positive and negative affect in In-game GEQ and positive and negative experience in Post-game GEQ. According to the findings from the analysis, we observed that there is a positive correlation between the positive affect and positive experience ($r=0.64$, $p<0.05$), while the other variables did not have correlations. *Table 11* shows correlations between In-game and Post-game GEQ variables.

Post-study interview

After the gameplay session, the elderly participants were asked about their opinions and feedback towards the Skiing game and digital game-based physical exercises. According to *Table 12*, we observed that 15 out of 21 elderly participants recommended that playing digital games can be an effective and effortless way of exercising, while 6 elderly participants did not agree on it. 20 elderly participants claimed that the Skiing game was easy to play, whereas one

Table 10. Correlations between In-game and Post-game GEQ variables

	Positive affect	Negative affect	Positive experience	Negative experience
Positive affect	1			
Negative affect	-0.11	1		
Positive experience	0.64*	0.01	1	
Negative experience	-0.69	-0.11	-0.49	1

participant disagreed. Regarding the in-game instruction, 17 elderly participants agreed that the adequate instructions were provided and they were easy to follow. However, 4 elderly participants did not support that statement. Finally, 20 elderly participants revealed that they were not afraid of making mistakes in the gameplay, whereas one participant was anxious about making mistakes.

Attitudes towards digital game-based exercise

After the gameplay session, the elderly participants were asked about their attitudes towards digital game-based exercise. Based on the findings from the analysis of data, the elderly participants claimed that digital game-based exercise is essential to good health (M=4.0) and game-based exercise is important to maintain all-around health (M=3.8), and the human body (M=3.4). Lastly, they mentioned that it can make one feel better (M=3.0). *Table 14* shows elderly participants' attitudes towards digital game-based exercise.

Based on the findings from the analysis of Post-game GEQ items in 5-point Likert scale (*Table 13*), we observed that more than 52% of elderly participants agreed that digital game-based exercise is essential to good health, whereas approximately 47% of them disagreed. More than 75% of elderly participants agreed on the fact that digital game-based exercises can work of their emotion, tension, and anxieties, whereas 14.29% did not agree on it. Noticeably, approximately 80% agreed that digital games can help a person improve and maintain his or her health while 4.76% was neutral and 14.29% strongly disagreed. Similarly, approximately 80% of elderly participants agreed that digital games can be beneficial to the human body while 19% did not agree on it. Lastly 33.33% strong agreed that digital game-based exercise can make one feel better while 14.29% just agreed. However, about 23% of elderly participants did not agree on it while 28.57% remained neutral. We also analyzed the difference between the elderly participants' attitudes towards physical exercises and digital game-based exercises by applying the Paired-Samples t-test. According to the findings from the analysis, we found that there was a significant difference between their attitudes towards physical exercises (M=4.9) and digital game-based exercises (M=3.6); $t(20) = -5.28$, $p < 0.05$. Furthermore, we also found that there was no correlation between the elderly participants' attitudes towards physical exercises and digital game-based exercises ($r = 0.004$, $n = 21$, $p < 0.05$).

Discussion

According to the findings from the analysis of the pre-study interview data, we observed that most of the elderly participants (20 out of 21) are active in physical exercises. They perform exercise activities daily or weekly. According to the pre-gameplay interview, we observed that their opinions towards participation in regular exercises are positive. For instance, they pointed out that engaging in regular physical exercises helps them remain active in old age. They also insisted that physical exercises improve their physical health as well as the social relationship with others. Based on these findings, we state that the elderly participants who were involved in our study are physically stable and active, and they participate in regular exercise routines.

The findings from the analysis of their responses towards the pre-study questionnaire highlight that most of them have highly positive attitudes towards physical exercises. They all recommended that doing physical exercises can help them improve health, reduce anxiety and tension, maintain all-around health, and makes them feel better. Furthermore, they are very much aware of the potential benefits of doing physical exercises. Based on this, we state that the elderly participants in our study have a very positive attitude towards physical exercises.

Table 11. Post-study interview questionnaire

Post-gameplay questions		Number of participants	
		Agree	Disagree
Perceived usefulness	Could playing digital games be an effective and effortless way of exercising?	15	6
Perceived ease-of-use	Was playing the game easy?	20	1
Gerontechnology self-efficacy	Were you able to play the game after receiving instructions? Would the user instructions have been adequate?	17	4
Gerontechnology anxiety	Were you afraid of making mistakes when playing the game?	1	20

Table 12. Elderly participants' attitudes towards digital game-based exercise

	Mean	Standard Deviation
Essential to good health	3	1.7
Helps to work of emotional tension and anxieties	3.9	1.4
Important in helping a person to gain and maintain health	3.8	1.3
Beneficial to the human body	4	1.5
Makes one feel better	3.4	1.4

Regarding their digital gameplay experiences, the findings highlight that most of the elderly participants (18 out of 21) in our study did not have prior experiences in playing digital games. We observed that they were not interested in digital games. Furthermore, they had misconceptions that digital games are not for elderly people, and it was a waste of time. Some elderly participants claimed that they did not like it and they did not have a device or gadget to play. Based on their comments, we state that the elderly participants in our study are non-gamers and they have no interest in it. More importantly, their attitudes towards digital games were relatively negative.

Based on the findings from the analysis of SUS, we observed that 16 out of 21 elderly participants provided a very positive feedback towards the usability of the Skiing game. The claimed that the game was easy to learn and play. It had clear in-game instructions, and adequate functions were integrated. The game context and gameplay were consistent. They mentioned that they had confident to play, and they would like to play it again more frequently. There were two elderly participants who rated the game as an average ('OK') and two participants who rated it negatively ('Poor'). One elderly participant rated it as ('Worst imaginable'). The elderly participants who provided negative feedback towards the game mentioned in the pre-study interview session that they had no interest in digital games. One of them had already stopped doing physical exercises due to her old age. Although there was a small number of participants who provided negative feedback towards the game, most of them supported that this game was easy to learn and play as well as user-friendly.

The findings from the analysis of In-game GEQ questionnaire, we observed that the elderly participants had a relatively high positive affection in playing the Skiing game, whereas they had a very low negative affection in the gameplay. The participants experienced a moderate success and absorption in the game. They were also relatively interested in the game as well as they thought that the game was not challenging for them. Apparently, they had almost no tension in the gameplay. Based on these findings, we state that the elderly participant's in-game experience in the Skiing game was moderately positive although most of them did not play digital games before.

With regard to the elderly participant's responses towards Post-game GEQ questionnaire, we observed that their positive experiences in playing the Skiing game were merely average. Except for the component 'Positive experience', the other components had a low mean score. Thus, we found that they have almost no negative experience, tiredness, and returning to reality. Based on this finding, we state that the elderly participants' post-game experience was moderately positive. We can take into consideration that the gameplay session was relatively short and most of them were non-gamers. Therefore, it might impact on the participants' experience in playing it. Regarding the correlation between In-game and Post-game elderly participants' experiences, we observed that their positive affection in the gameplay can affect on their post-game positive experiences.

According to the findings from the analysis of the post-study interview questions, we found that the majority of elderly participants (15 out of 21) recommended that digital game-based exercise can be an effective and effortless way of doing physical exercises. They expressed in the post-study interview session that they would like to try it again and they would like to play a variety of digital games. Some proposed their ideas of playing digital game-based

Table 13. Elderly participants' attitudes towards digital game-based exercise in 5-point Likert scale

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think digital game-based exercise is essential to good health.	33.33%	14.29%	0.00%	23.81%	28.57%
I think digital game-based exercise can help to work of emotional tension and anxieties.	14.29%	0.00%	9.52%	38.10%	38.10%
I think digital game-based exercise is important in helping a person gain and maintain all-around health.	14.29%	0.00%	4.76%	52.38%	28.57%
I think digital game-based exercise is beneficial to the human body.	19.05%	0.00%	0.00%	23.81%	57.14%
I think regular digital game-based exercise makes one feel better.	19.05%	4.76%	28.57%	14.29%	33.33%

exercises such as Bowling, Golf, Cycling, and Dancing. Most of them agreed that the Skiing game was an easy, simple, and effective way of doing exercise. We also observe that although most of them have had negative views on digital games, they have become interested in the digital gameplay as an alternative form of doing exercises. They expressed their enjoyment in the gameplay and desire to play in the future. Based on the findings from the post-study interview, we state that the most elderly participants supported that digital games can be an effective form of physical exercise for them.

The findings from the analysis of the elderly participants' attitudes towards digital game-based exercise show that after the gameplay, their attitudes have changed more positively towards playing digital games for physical exercises. Although they had a relatively negative attitude towards digital games before, they were quite positive that digital games are promising for improving and maintaining health. Furthermore, they commented that it can reduce their tension and the level of anxiety. They have a moderately positive view on digital games that it can be beneficial to human body and it can help a person feel better. Regarding the differences between the elderly participants' attitudes towards physical exercises and digital game-based exercises, we observed that they have more positive attitudes towards physical exercises. However, the findings also show that their attitudes towards digital game-based exercises are noticeably positive. Therefore, we can say that digital game-based exercises are also promising for promoting elderly people's physical exercises. We also found that there is no correlation between the elderly participants' attitudes towards physical and digital game-based exercises. It means that having positive attitudes towards traditional physical exercises does not have an influence on their attitudes towards digital game-based exercises.

Based on the observational study and interview sessions, we recommend usability and game design guidelines for designing digital game-based physical exercises for elderly people. For the game user interface, elderly people prefer simple and unclutter user interface so that they can play the game without distraction. We also observed that visual cues are important for elderly players so that they can easily understand how to succeed game tasks. In-game instructions are important for them to play. For interaction design, they prefer motion-based interaction, which is natural and easy for them. The elderly participants also pointed out that they liked to perform game actions that can be familiar to them (e.g. Skiing activity in this study). For game design, the elderly participants suggested that a variety of games and different gameplay will be more interesting. We found that repetitive game action is less interesting for them. We also observed that game calibration and customization are also important to meet the needs of elderly people's abilities in physical movements. Lastly, we observe that elderly people's safety in the gameplay is highly important because most of them expressed their concern for being fallen while playing.

In summary, we observed the following findings from this study. First, although the elderly participants had a moderately negative attitude towards digital games before they had played the game, they had changed their attitudes positively after they gameplay. Second, the elderly participants recommended that playing digital games can be an effective way of exercising for them. Third, the Skiing game is an easy and user-friendly for the elderly participants. More importantly, the usability and game design guidelines observed in this study can be useful and insightful for our future game development, as well as other practitioners in the related areas. Lastly, the elderly participants' overall in-game and post-game experiences were moderately positive although most of them had no prior experiences in playing digital games. In addition, we learned from the findings from GEQ analysis, creating positive experiences for elderly players in the game can positively impact on their post-game user experiences that can lead to their continuation and interest in playing digital games in the future. The findings from this usability study can be helpful and can provide some insights for researchers and practitioners into utilizing and adopting digital game technologies to promote elderly people's physical well-being in terms of physical exercises and rehabilitation.

For the key contributions of this study, firstly, the findings from this study support the existing literature that digital games are promising for elderly people's physical well-being in terms of physical exercises[12,13,15-17]. Secondly, user-friendly and easy digital games can change elderly people's negative attitudes and misconceptions about playing digital games in old age. Thirdly, the findings from this study show that digital games can be an alternative solution for elderly people to promote their physical exercises. Lastly, the usability and digital game design guidelines identified in this study can provide other designers in designing user-friendly digital games for elderly people.

Conclusion

In this study, we evaluated the user experiences and usability of digital game-based Skiing exercise with 21 Finnish elderly participants at one of

the elderly service homes in Finland. The main objective of this study is to investigate Finnish elderly participants' user experiences and the usability of the game for them. Furthermore, we aimed at investigating their attitudes towards physical exercises and digital game-based exercise. Then, we studied if digital games can be an alternative solution for their physical exercises. The findings show that most of the elderly participants in this study are physically active, and their attitudes towards physical exercise are highly positive. Although most of them did not have prior experiences in playing digital games, their feedback towards the usability of the Skiing game is quite positive. In addition, their in-game and post-game experiences were moderately positive. Noticeably, despite having negative attitudes towards digital games before, after the gameplay, their attitudes towards digital games have changed. They also recommended that playing digital games can be beneficial for their physical health. Based on the findings from this study, we conclude that digital games are promising and have the potentials to improve elderly people's physical exercise activities, and it can be used as an alternative solution to promote their physical well-being. The findings from this study can be helpful for people who are interested in using digital games for elderly people's physical well-being.

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Investigating the Finnish elderly people's attitudes and motivation towards digital game-based physical exercises

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Abstract

Attitudes and motivation towards physical exercises play a vital role for elderly people's adherence to exercise. In recent years, digital games have been used to enhance elderly people's experiences in physical exercises. However, there is a limited number of studies regarding elderly people's attitudes and motivation towards digital game-based exercises. In this study, we aim at investigating the Finnish elderly people's attitudes towards physical and digital game-based exercises, as well as their motivation in the gameplay. Furthermore, we intend to investigate if digital games can be an alternative way of exercising for elderly people. We conducted a user experience test of the *"Skiing Game"* with 21 elderly participants in Finland. We applied both qualitative (e.g. interview) and quantitative (e.g. questionnaires) methods to collect data from the participants. Then, we analyzed the data by using SPSS and Nvivo. The findings show that the Finnish elderly people's attitudes towards physical exercises are more positive than digital game-based exercises. However, their attitudes towards digital games have become more positive after the gameplay. Their in-game and post-game user experiences were moderately positive. Their motivation to play digital game-based exercises was moderately high after the gameplay. Their feedback towards the Skiing game was positive. They recommend that digital game-based exercises can be an effective way of exercising. Based on these findings, we recommend that digital games are promising to be used as an alternative way of exercising for the Finnish elderly people. The discussion in this study can help researchers gain insights about using digital games for promoting elderly people's participation in physical exercises.

Keywords: digital games, usability, gamification, user experience

Introduction

Every year, 38 million people die due to non-communicable diseases (NCDs), including heart attacks, stroke, and diabetes [1]. One of the major causes of NCDs is physical inactivity, which is often associated with ageing population. Physical inactivity is one of the risk factors for death [2]. According to Taylor [3], there is a positive association between elderly people's health improvements and their active participation in exercises.

Peterson et al. [4] mentioned that age-related declines (e.g. limited mobility) can negatively impact on elderly people's quality of life, including activities of daily living and functional abilities. Regular physical exercises can

minimize the functional declines of elderly people. Functional independence is one of the important factors to have a quality of life for elderly people [5]. Physical exercises play an important role in improving elderly people's health such as cognitive function, mental health, physical fitness, and social engagement [6]. Although physical exercises have the potential to improve elderly people's physical well-being, it is still a challenge for healthcare professionals to encourage them to actively participate in regular exercise activities [3].

In recent years, digital games have been used to improve elderly people's physical well-being such as engagement and participation in regular exercise routines [7], rehabilitation [8], and fall prevention [9]. It has been also used for elderly people's social connection, including intergenerational communication between the older and the younger generation [10]. Furthermore, digital games can improve elderly people's cognitive abilities, including cognition, attention, spatial vision, and memory [11].

Many studies reported the positive impacts of digital games on elderly people, including physical health, socialization, and cognition; however, there is a limited study on understanding elderly people's attitudes towards digital game-based exercises, as well as their motivation in playing digital games as an exercise activity. Mäkilä et al. [12] indicated that to develop physical exercise interventions for elderly people, it is important to understand their attitude, motives, and barriers to participation in physical activity.

In this study, we aim at understanding the Finnish elderly people's attitudes towards physical and digital game-based physical exercises, as well as their differences. We are also interested in investigating their motivation in playing digital game-based exercises. We conducted a user experience test of a digital game-based exercise called the 'Skiing Game' with 21 Finnish elderly participants (>60 years old) at an elderly service home in Finland. We used questionnaires, in-depth interviews, and observations to investigate their attitudes, motivations, and user experiences in playing the Skiing game.

Based on the findings from this study, we discuss the Finnish elderly participants' attitudes and motivation towards digital game-based exercises. We also discuss their user experiences and the potential of digital game-based exercises as an alternative solution for elderly people. The discussion in this paper can help researchers and practitioners gain insightful knowledge into using digital games for promoting elderly people's participation in physical exercises and the adoption rate of digital game-based exercises among elderly people. The main objectives of this study are:

- To investigate the Finnish elderly people's attitudes towards physical exercises in general and digital game-based exercises,
- To find out their motivation in playing digital game-based exercises,
- To investigate their user experiences in playing the Skiing game, and
- To examine if digital game-based exercises can be an alternative way of exercising for the Finnish elderly people.

Background

Understanding elderly people's attitudes towards physical exercises

Attitude is defined as 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavour [13]'. Petty and Cacioppo [14] also defined 'Attitude' as a general and enduring positive or negative feeling about some person, object, or issue. Attitude is also related to a particular thing that is liked or disliked [15]. Attitude is one of the most important indicator variables that has a relationship to behavioral intentions regarding physical activity [16]. Regarding elderly people's participation in physical exercise activities, attitude is one of the key determinants that can have an influence on long-term participation [17]. The researcher also indicated that a person's attitude is one of the important factors that can

influence on the successful compliance of long-term physical exercises [17].

Almeida and Rui [18] pointed out that there is a strong relationship between physical activities and a person's attitudes because if the attitudes are manifested by behaviours, more positive beliefs about physical activities are likely to become more evident with more active behaviour and adherence to physical exercise practices. Regarding elderly people's attitudes towards physical exercises, Pappous et al. [19] stated that the elderly who reported more positive attitudes toward physical exercise showed better adherence rates. According to the literature, we found that there has been a limited study on elderly people's attitudes towards physical exercises [19].

Understanding elderly people's motivation in physical exercises

According to Wright and Wiediger [20], motivation is defined as "motivated behaviours as arising from a physiological and/or psychological need or desire. This need or desire activates and directs the individual toward appropriate goals that will hopefully satisfy this arousal". Petri and Govern [21] defined motivation as "a constant flow of behaviour that can be directed in many different ways".

Many studies suggested that physical activities and exercises are beneficial for elderly people. However, a challenge for healthcare professionals is how to motivate them to participate in regular exercise activities [3]. Brauner and Ziefle [22] indicated that participating in regular physical exercises can help elderly people reduce their risk of chronic disease (e.g. diabetes), improve their functional and cognitive abilities, avoid injuries (e.g. falls), and live more independently. The authors also highlighted that it is important to study how we effectively motivate elderly people to change their exercise behaviours and stay actively in old age [22]. According to the Mayo Clinic [23], motivation plays a key role in doing physical exercises.

Petersen [24] pointed out that motivation can be a significant barrier for elderly people to initiate physical exercise activities. Justine et al. [25] also indicated that lack of motivation is one of the important factors that have an influence on elderly people's inactivity in physical exercises. Kravitz [26] highlighted that elderly people's lack of motivation in physical exercises can lead to low adherence and termination from regular exercise routines. To overcome a barrier of lack of motivation for elderly people, they should try new and different exercise options, and find ways to make the workout sessions more enjoyable [26]. Based on the literature, in this study, we will introduce digital game-based exercises to the Finnish elderly people and investigate whether digital games can impact on their motivation to exercise.

Elderly people's user experiences in gameplay

User experience (UX) is defined as "focusing on having a deep understanding of users in a specific user group, especially what they need, what they want, what they value, their abilities, problems, and also their limitations" [27]. According to Alben [28], UX is also defined as "all the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it". In this study, we are interested in investigating the Finnish elderly people's user experiences in playing the Skiing game. Thus, to understand elderly people's user experiences, we applied the Game Experience Questionnaire (GEQ), which is widely accepted by researchers in game UX [29]. According to Norman [30], GEQ is a reasonable and applicable tool in investigating a player's experiences with a game. The author also stated that the GEQ questionnaire has been widely and successfully used in many studies. Basically, GEQ has two modules to assess the player's experience, including in-game and post-game [29]. The GEQ in-game module can be used to assess a player's game experience during a game-play session. It includes seven components: Sensory and Imaginative Immersion, Flow, Competence, Positive Affect, Negative Affect, Tension,

and Challenge. For the GEQ post-game questionnaire, it can be used to assess how players felt after they have played the game. It has four components, including Positive Experience, Negative Experience, Tiredness, and Returning to Reality.

Related studies

Regarding elderly people's attitudes towards digital games, we found that there is a very limited number of studies on this topic. According to Brauner et al. [22], serious and pervasive games can change elderly people's attitudes, which can promote their healthy behaviors. Theng et al. [10] conducted a pilot study with 14 pairs of elderly-teenager participants to examine the effects of the Nintendo Wii games on the social communication between two generations (old and young). Their findings showed that the elderly group showed more positive attitudes towards the younger group through the gameplay.

With regard to elderly people's motivation in playing digital game-based exercises, Albaina et al. [31] designed and developed a persuasive system called "A Virtual Coach", which aims to motivate and encourage elderly people to exercise more. They co-designed the system with elderly participants, and the preliminary findings from the early evaluation with a small number of participants showed that they were motivated to exercise more through the digital gameplay. Brox et al. [32] conducted a review on how exergames can motivate elderly people to exercises regularly. They reviewed existing games, including Nintendo Wii games and Dance Dance Revolution. The researchers suggested that exergames have the potential to motivate elderly people to be more physically active, and it can be used as a supplement to physical training [32].

Jessen et al. [33] used a simple, fun, and challenging modular tile-based computer games to motivate elderly people for their physical activities. The researchers evaluated the game with 40 elderly participants at elderly centers, rehabilitation center, and hospital. They found that the introduction of modular tiles games was successful and highly motivating. Their findings showed that playing digital games can create a strong motivation for elderly people to participate in therapeutic training as well as to improve in measurable health outcomes. Nap et al. [34] investigated the motivation, preferences, and needs of elderly gamers, and they found the underlying motivation factors for elderly people to play digital games, including fun and relaxation, escape from reality, social connectedness, and meaningful play to their daily lives.

Research questions

The existing literature highlighted that attitude plays an important role in elderly people's participation in regular physical exercises. Furthermore, digital games have the potential to motivate elderly people to do regular physical exercises. Based on the findings from the literature, in this study, we aim at investigating the Finnish elderly people's attitudes towards physical and digital game-based exercises, and their motivation in playing digital game-based exercises. We also aim to investigate the potential of digital game-based exercises as an alternative way for elderly people to exercise. In this study, the following research questions are formulated:

- What is the difference in the Finnish elderly people's attitudes between physical and digital game-based exercises?
- What is the Finnish elderly people's motivation towards digital game-based exercise?
- Is there a correlation between the Finnish elderly people's attitudes and motivation towards digital game-based exercise?

A user experience test

We conducted a user experience test with 21 Finnish elderly participants at one of the elderly homes in Finland called 'Ruusukortteli'. The study took two days: 17 elderly participants for day-one and 4 participants for day-two respectively. Three researchers from the University of Turku were involved in the study to guide

elderly participants in playing the Skiing game and to ask questionnaires, as well as to conduct the interview.

Skiing game

In this user experience test, we used a digital game-based physical exercise called 'Skiing Game' (See Figure 1). Before we designed and developed the Skiing game, we conducted a number of pre-studies that included understanding the usability of existing commercial games [35,36], the usability testing of 'SportWall' game [37], the usability testing of multimodal input devices for elderly people [38-41], and the literature review on digital games for elderly people [35]. Based on the findings from the pre-studies, the Skiing game was designed and developed by the developers from the Turku Game Lab in Finland, especially aiming for the Finnish elderly people.

The main objective of the game is to improve the Finnish elderly people's participation in regular exercises by utilizing digital games as an alternative solution. In the Skiing game, we used a simple, easy, and age-friendly game interface, context, and gameplay. For the gameplay, we used a popular cross-country Skiing activity, which is familiar to most of the Finnish elderly people. Regarding user's interaction experience, we used a controller-free interaction for elderly people by using the Xtreme Reality Technology. For the technical environment, we used the Unity3D game engine with C# programming language to implement this game. In this game, a player needs to continuously move both hands forward and backward to skii in the game. In addition, a player simply needs to move his or her body to the left or right to avoid obstacles in the game.

Elderly participants recruitment

We recruited elderly participants at the elderly service home 'Ruusukortteli' in Finland. Before the study was undertaken, we collaborated with the healthcare professionals from the elderly service home for the recruitment, study design, protocol, and procedures. Regarding the inclusion criteria for elderly participants, they should be aged 60 years and above. He or she should have a stable health condition physically and mentally. In addition, they should be able to tolerate for at least 10 minutes to play the game in a standing position. They also should have no neurological or cognitive deficits. Based on these criteria, we recruited a total of 21 elderly participants: 14 female and 7 male participants with an age range between 60 and 87 years (M=76). More importantly, we requested a consent from every participant to be involved in this study, as well as a permission for the video-recording.

Figure 1. The Skiing game.

User experience test design and procedure

Before the elderly participants played the game, a researcher asked the pre-study interview questions, including their demographics, physical activities, and attitudes towards participation in regular physical exercises. The pre-game interview session took about 15 minutes. Then, the elderly participants went through a game tutorial guided by a researcher, followed by the actual gameplay for 15 minutes. After playing the game, a researcher asked the individual elderly participant the post-game questionnaires and interview questions, including in-game and post-game user experiences, their motivation, and attitudes towards digital game-based exercises. Furthermore, we also asked the general interview questions regarding their feedback and opinions towards the Skiing game and digital game-based exercises. The post-interview session took about 15 minutes. The gameplay and data collection for the individual participant took 45 minutes approximately. During the gameplay session, we observed the elderly participants' behaviours, expression, emotion, and feedback towards the game by using a video recorder and a note-book. Table 1 shows the design and procedures of the user experience test of the Skiing game.

Questionnaires

We used different questionnaires to investigate elderly people's opinions towards digital game-based physical exercises. Firstly, we created the questionnaires to understand elderly people's attitudes towards physical exercises, based on 'the attitudes of older adults toward physical activity and exercise' developed by Terry et al. [42]. To investigate elderly people's user experiences during and after the gameplay, we used Game Experience Questionnaires (GEQ), which includes two modules: in-game and post-game to assess player's user experiences [29]. The in-game GEQ questionnaires investigate players' experience while they are playing a particular game, and it contains seven components including competence, challenge, negative effect, and positive effect.

Post-game GEQ questionnaires are used to find out how a player feels right after the gameplay, and it contains four components such as positive and negative experiences, tiredness, and returning to reality respectively. Both in-game and post-game GEQ questionnaires are created based on the 5-point Likert scale from "Not at all (0)" to "Extremely (4)". Regarding the questionnaires for elderly people's attitudes towards game-based physical exercise, we used the same questionnaire developed by Terry et al. [42].

For the questionnaires about elderly people's motivation, we used Intrinsic Motivation Inventory (IMI) developed by Plant and Ryan [43], which determines the levels of intrinsic motivation of a person. The IMI is a multidimensional measurement tool that is used to assess participants' subjective experience related to a particular activity in laboratory experiments and has been used in several experiments related to intrinsic motivation [44]. We created the post-interview questions based on the Senior Technology Acceptance & Adoption Model (STAM) [45].The questions include four items that investigate elderly people's perceived usefulness, perceived ease-of-use, gerontechnology self-efficacy, and gerontechnology anxiety. Figure 2 shows a photo of an elderly participant in the study of the Skiing game.

Table 1. User experience test design and procedure.

Task	Duration	Description
Introduction to the game Pre-study interview	15 minutes	Pre-study session
Game tutorial Gameplay	15 minutes	Gameplay session
Post-study interview	15 minutes	Post-study session

Figure 2. A user experience test of the Skiing game.

Ethical consideration

In this study, we followed the instructions and guidelines created by the University of Turku to conduct a particular user testing with human subjects, especially elderly participants. Furthermore, we obtained an approval from the elderly service home in Finland before we conducted the test. More importantly, we requested the individual participant's consent before he or she participated in the study.

Data analysis

In this study, we collected both qualitative and quantitative data from the user experience test of the Skiing game with the Finnish elderly participants. For qualitative data collection, we used interviews and observation to investigate the elderly participants' feedback, comments, and opinions towards traditional physical exercises as well as digital game-based exercises. For quantitative data collection, we used questionnaires for pre and post studies. After collecting both qualitative and quantitative data, we conducted the analysis of data to explore the elderly participants' attitudes and motivations in playing digital game-based exercises, as well as their experiences in the gameplay. For the qualitative data analysis, we quoted the participants' feedback, comments, and opinions. Then, we quoted and categorized the relevant findings, followed by decategorization until we identified important themes, relationships, trends, and information. For the quantitative data analysis, we used SPSS, the statistical tool, to analyze the data collected from the elderly participants' responses to GEQ questionnaire, including in-game and post-game modules.

Results

Elderly participants' attitudes towards physical exercises

Based on the findings from the pre-study interview sessions, we found that 19 out of 21 elderly participants are active in regular physical exercises, which include walking, cycling, aerobics, and stretching. Only two participants had already stopped doing physical activity due to their old age: 85 and 87 respectively. Among the elderly participants who are active in regular physical exercise activities, only six elderly participants usually do daily exercises for one to two hours. All of them do weekly regular physical exercises for at least six hours.

Regarding the elderly participants' attitudes towards physical exercises, we found that they have a highly positive attitudes towards participation in regular physical exercises. All questionnaire items earned the highest scores (M=5.0) except the questionnaire item-2 'Physical exercise helps to work of emotional tension

and anxieties' (M= 4.9). Table 2 shows the mean scores and the standard errors of the questionnaires about elderly people's attitudes towards physical exercises, and Figure 3 demonstrates the graphical representation of it.

Table 2. Elderly participants' attitudes towards traditional physical exercises.

Questionnaire	Mean Score (M)	Standard Error (SE)
Q1. Physical exercise is essential to good health.	5.0	0.0
Q3. Physical exercise is important in helping a person to gain and maintain all-around health.	5.0	0.0
Q4. Physical exercise is beneficial to the human body.	5.0	0.0
Q5. Regular physical exercise makes one feel better.	5.0	0.0
Q2. Physical exercise helps to work of emotional tension and anxieties.	4.9	0.1

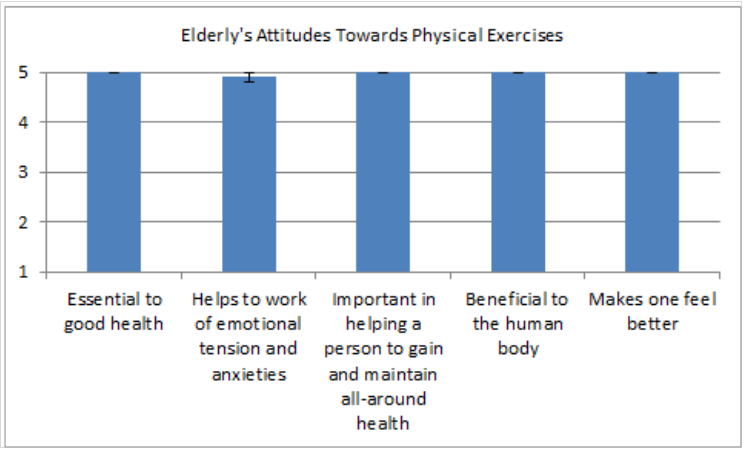

Figure 3. Graphical representation of elderly participants' attitudes towards physical exercises.

Elderly participants' in-game user experiences (GEQ)

Regarding the elderly participants' in-game user experiences (See Table 3), we observed that they had a relatively high positive affection (M= 3.0) during the gameplay, whereas they had almost no negative affection (M= 0.1). The in-game GEQ components 'Flow' (M= 2.6), 'Competence' (M= 2.3), and 'Sensory and Imaginative' (M= 2.3) had an average mean score. We also found that the component 'Challenge' had a noticeably low mean score (M= 1.2), while the elderly participants had almost no tension in the gameplay (M= 0.2). Table 3 shows the means scores of elderly participants' in-game user experiences, and Figure 4 shows a graphical illustration of it.

Elderly participants' post-game user experiences (GEQ)

For the elderly participants' post-game user experiences, we observed that 'Positive Experience' had an average mean score (M= 2.0), while other components had a noticeably low mean score, smaller than (M=1.0). The component 'Returning to Reality' had a mean score (M= 0.8). We also found that the elderly participants had almost no tiredness and negative experience (M= 0.1). Table 4 shows the mean scores of the post-game GEQ and the standard errors and Figure 5 shows the graphical representation of post-game GEQ mean scores and standard errors.

Table 3. The in-game GEQ mean scores and the standard errors.

In-game GEQ components	Mean Score (M)	Standard Error (SE)
Positive Affect	3.0	0.2
Flow	2.6	0.3
Competence	2.3	0.0
Sensory and Imaginative	2.3	0.3
Challenge	1.2	0.2
Tension	0.1	0.1
Negative Affect	0.1	0.1

*The highest score is 4.0 and the lowest score is 0.0.

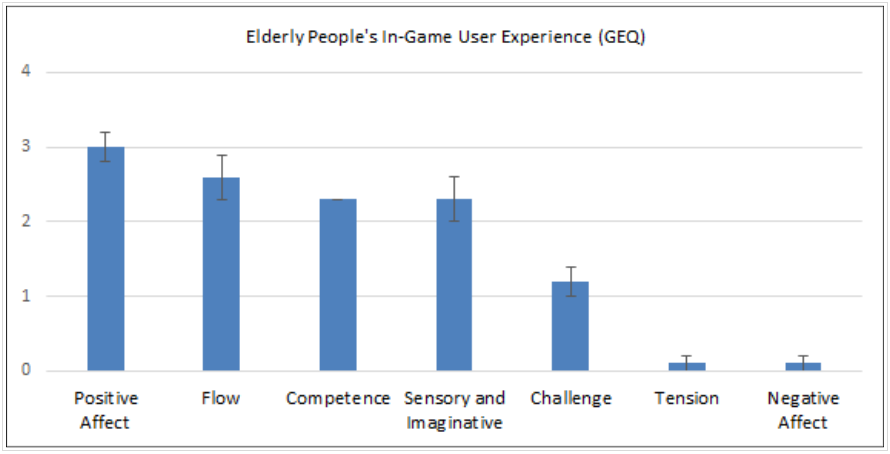

Figure 4. Graphical representation of elderly participants' in-game GEQ mean scores and the standard errors.

Table 4. The post-game GEQ mean scores and the standard errors

Post-game GEQ components	Mean Score (M)	Standard Error (SE)
Positive experience	2.0	0.2
Returning to reality	0.8	0.2
Negative experience	0.1	0.0
Tiredness	0.1	0.0

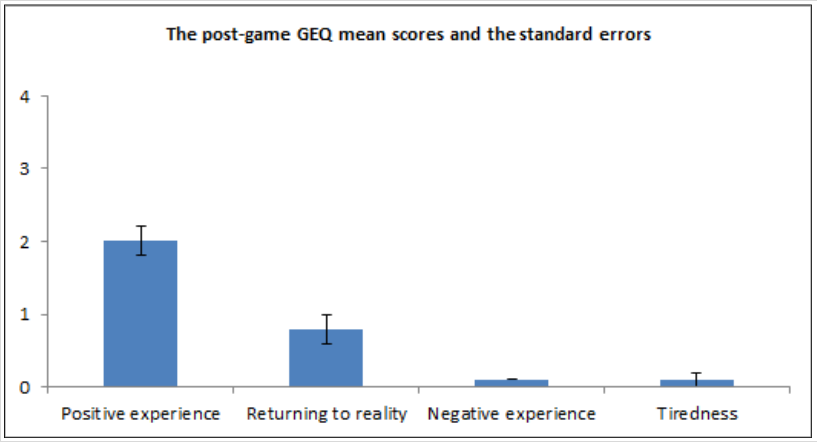

Figure 5. Graphical representation of post-game GEQ mean scores and the standard errors.

Elderly participants' motivation towards digital game-based exercise

Regarding the elderly participants' motivation towards game-based exercises, we observed that all questions had the mean score above 3.0, whereas only question 4 received the mean score 2.2. The elderly participants claimed that playing digital games is useful for doing physical exercises (M=3.5), as well as it can improve their motivation to do physical exercises (M=3.5). Most of them answered that they were willing to try the game again (M=3.5). In addition, they believed that playing digital games could be valuable to their daily and weekly exercises (M=3.3). Lastly, they reported that it could help them to do more physical exercises than before. Table 5 shows the mean scores and the standard errors of elderly's motivation towards game-based exercises. Figure 6 shows the illustration of it.

Table 5. Elderly people's motivation towards digital game-based exercise.

Motivation Questionnaires	Mean Score (M)	Standard Error (SE)
Q2. I think that doing this activity is useful for doing physical exercises.	3.5	0.3
Q3. I think this is important to do because it can improve my motivation to do physical exercises.	3.5	0.3
Q5. I would be willing to do this again because it has some value to my daily/weekly physical exercises.	3.5	0.3
Q1. I believe this activity could be of some value to my daily/weekly physical exercises.	3.3	0.3
Q4. I think doing this activity could help me to do more physical exercises than before.	2.2	0.3

*The highest score is 5.0 and the lowest score is 1.0.

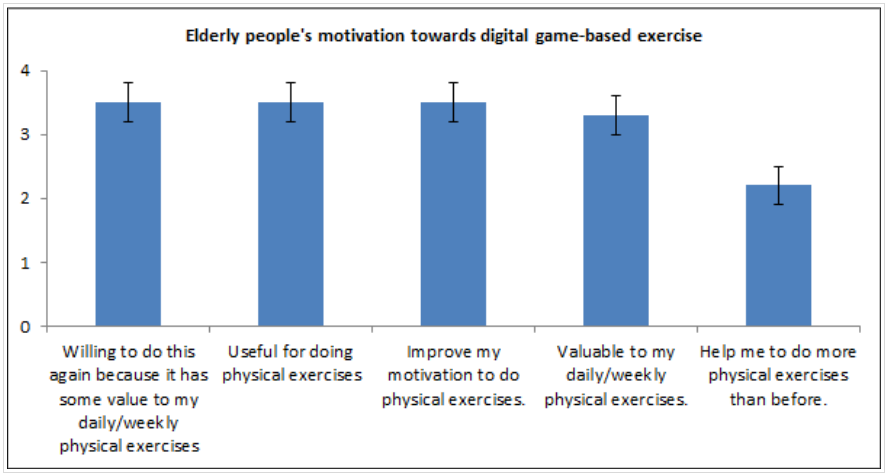

Figure 6. Graphical representation of the mean scores and the standard errors of elderly's motivation towards game-based exercises.

Elderly participants' attitudes towards digital game-based exercises

For elderly participants' attitudes towards digital game-based exercises, we found that after the gameplay, the elderly participants have changed their attitudes more positively than before. They claimed that digital game-based exercises can be beneficial to their body (M=4.0) and regulation of emotional tension and anxieties (M=3.9). They claimed that digital gameplay can help them maintain all-around help (M=3.8), and make them feel better (3.4). Lastly, most of them agreed that it is essential to good health (M=3.0). Table 6 shows the mean scores of elderly participants' attitudes towards digital game-based exercises. Figure 7 illustrates a graphical representation of elderly participants' attitudes towards digital game-based exercises.

Table 6. Elderly participants' attitudes towards digital game-based exercises.

Questionnaires	Mean Score (M)	Standard Error (SE)
Q4. I think game-based exercise is beneficial to the human body.	4	0.3
Q2. I think game-based exercise can help to work of emotional tension and anxieties.	3.9	0.3
Q3. I think game-based exercise is important in helping a person gain and maintain all-around health.	3.8	0.3
Q5. I think regular game-based exercise makes one feel better.	3.4	0.3
Q1. I think game-based exercise is essential to good health.	3	0.4

*The highest score is 5.0 and the lowest score is 1.0.

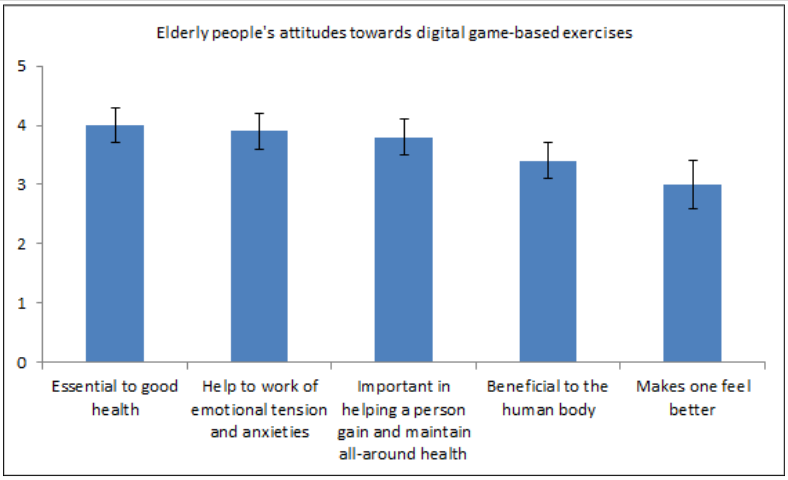

Figure 7. Graphical representation of elderly participants' attitudes towards digital game-based exercises.

We analyzed the difference in the elderly participants' attitudes between physical and digital game-based physical exercises by applying the Paired-Samples t-test. Based on the findings from the analysis, we found that there was a significant difference in the scores for physical exercises (M=4.9) and digital game-based physical exercises (M=3.6); $t(20) = -5.28$, $p < 0.05$. We also observed that there was no correlation between the elderly participants' attitudes towards physical exercises and digital game-based exercises ($r = 0.004$, $n = 21$). We assessed the relationship between the elderly participants' attitudes and motivation towards digital game-based exercises after the gameplay. We observed that there was a positive correlation between the two variables ($r = 0.75$, $n = 21$). Overall, the results showed that the increment of the elderly participants' positive attitudes was correlated with the increment in their motivation in the gameplay.

Post-gameplay interview

Based on the findings from the post-study interview questions, 15 out of 21 elderly participants agreed that playing digital games can be an effective and effortless way of exercising, whereas 6 elderly participants disagreed. We observed that all elderly participants claimed that the Skiing game was easy to play except one participant. We also found that 17 elderly participants commented that the game provided adequate in-game instructions. However, four elderly participants did not agree on this. Lastly, 20 elderly participants were not afraid of making mistakes during the gameplay, but one participant was anxious about it. Table 7 shows the elderly participants' responses towards the post-study interview questions.

We also conducted a post-study interview session with the individual elderly participant regarding their opinions and feedback towards digital game-based physical exercises. Based on the findings from the analysis of interview comments, we reported the classifications of the elderly people's comments towards the game (See Table 8). The elderly participants commented that digital games can be an alternative way of doing physical exercises. Most elderly participants suggested that traditional physical exercises came as a first priority. They recommended digital games as an another option when they can't have access to physical exercises and outdoor activities due to barriers including poor health, weather, lack of facilities, and long distance to sports center or gym. For instance, one elderly participant commented that "This could be good if you can't work out normally. Because at home, people don't do physical activity without an example".

Table 7. The percentages of post-gameplay questionnaires.

Post-Gameplay Questionnaires		Yes	No
Perceived usefulness	Could playing digital games be an effective and effortless way of exercising?	15	6
Perceived ease-of-use	Was playing the game easy?	20	1
Gerontechnology self-efficacy	Were you able to play the game after receiving instructions? Would the user instructions have been adequate?	17	4
Gerontechnology anxiety	Were you afraid of making mistakes when playing the game?	1	20

Table 8. Elderly's comments in the post-game interview.

An alternative solution	"Yes…… it could be in the autumn when it rains. But preferably I would go out to exercise" "…a rainy day does not prevent going out to exercise. But in the morning and evening, I could put the game on and ski"… "It might be good if you can't go out. It would be fun if you are alone" "Difficult question. Real exercise comes first. When the time comes that you cannot exercise for real then this is good". "If you don't exercise then it is a good start". "…it's good for spending time…" "….This could be good if you can't work out normally. Because at home, people don't do physical activity without an example" "This helps to stay at home".
User experiences	"I get excited" "It made me curious. Playfulness made me excited". "Nice but if it could be used often…" "….Interesting. More reasonable than shooting games". "…Easy and fun". "…I was amazed from this game. It was simple". "It was meaningful. It made my heart beat, I liked it".
Usefulness	"….for physical exercise and socializing with others". "It can improve my movements if I play at home regularly…" "….useful for exercise training"
Ease-of-play	"For a first-timer it was easy". "At first it was difficult after it became easier..." "It was easy when I understood the idea…." "…it was easy/effortless. Didn't need to use strength nor my brain".
User Interface	"Clear. It went better when I knew what was going to come next" "The picture made it clearer" "Picture and info…" "Yes. A picture would have been of help" "Nice scenery. *Lapland* came into my mind…" "I couldn't believe that I would experience this, it was very enjoyable. Beautiful scenery".
In-game Instructions	"I believe that instructions are adequate. A demo would be good." "Oral/verbal instructions are better." "It would be good if somebody tells instructs you, especially with stepping left and right." "Oral/verbal instructions are better"
Game Support	"Having an instructor is a good thing" "A demo would be good…"

For user experiences, we learned from the findings that most elderly participants commented that it was an interesting, fun, and exciting experience for them. One elderly participant highlighted that the Skiing game is more reasonable than shooting games, and the other elderly advocated that it was a meaningful play. Overall, the elderly participants' comments towards their experiences in playing the Skiing game was quite positive. Regarding the usefulness of the game, the elderly participants recommended that digital game-based exercise can improve their physical activities. In addition, it can enhance their socialization with others through co-gameplay. Regarding the ease-of-play of the game, the elderly participants insisted that it was an easy game for non-gamer players if they knew how to play it. Furthermore, they suggested that the gameplay was effortless and easy to follow. They commented that it can be useful for their physical exercise activities.

We also observed the useful usability and game design guidelines for designing digital game-based physical exercises for elderly people. First of all, the elderly participants highlighted that the pictures and information provided in the game were clear and easy to learn. They recommended that the graphical representation of the game was helpful for them in the gameplay. One of the elderly participants commented that the game context reminded him of a famous land called "Lapland", which is situated in the northernmost region in Finland where ski resorts are built. The elderly participants also mentioned that they could connect to the game context and gameplay because of the familiar game contents.

The elderly participants highlighted the importance of effective in-game instructions. Some elderly participants suggested that verbal instruction in the gameplay will be helpful for them to be able to understand the game more easily. Lastly, the elderly participants provided insightful comments towards game system support, highlighting the importance of effective tutorial and instructor for them in the game. Table 8 shows the classification and compilation of comments made by the elderly participants.

Discussion

Elderly people's attitudes towards physical and digital game-based exercises

Regarding the elderly participants' attitudes towards physical exercises, they agreed that doing physical exercises is essential and beneficial to good health and the human body, and it plays a major role in maintaining all-around health. In addition, they highlighted that regular exercise activities can make a person feel better. They also pointed out that playing digital games can help to work of emotional tension and anxieties. Based on the findings from the pre-study questionnaire, we learned that the elderly participants have a very high positive attitude towards physical exercises. They are also aware of the benefits of doing regular physical exercises.

Regarding their experiences in digital gameplay, most of them did not have prior experiences. Before they played the game, their attitudes towards digital games were moderately negative. Most of them mentioned that they were not interested in digital games, and it was a waste of time. Some of them claimed that they did not have a device to play. They had a misconception that playing digital games is only for the younger people, and not suitable for elderly people. Based on the findings from the pre-study interview, we state that the elderly participants had a relatively negative attitude towards digital games prior to the gameplay.

However, the findings from the questionnaire showed that after they had played the game, the elderly participants had a relatively high positive attitude towards digital game-based exercises. They had a moderately high positive attitude that digital game-based exercises are essential to good health, and it can help to regulate emotion, tension, and anxiety. In addition, it can support the maintenance of all-around health for them. They had a moderately positive attitude that digital games can be beneficial to human body. Lastly, they showed their average positive attitudes towards digital games that it can make them feel better. This finding is also in line with the finding by Brauner et al. [22] that serious games or digital game-based exercises can

change elderly people's attitudes in doing physical exercises.

According to the findings from the analysis of the comparative analysis using a t-test, we found that the elderly participants' attitudes towards physical exercises are significantly more positive than digital game-based exercises. We can take into account that most of the elderly participants never played digital games before, and it was the first attempt for most of them. Thus, it may impact on their attitudes towards digital game-based exercises. Although the elderly participants showed more positive attitudes towards physical exercises, we learned that their attitudes towards digital games for physical exercises have changed noticeably more positive after the gameplay. We also observed that the elderly participants' attitudes did not have a relation to their attitudes towards digital game-based exercises.

Elderly people's motivation in playing digital game-based exercises

Regarding the elderly participants' motivation in playing digital game-based physical exercises, we observed that they had a relatively high motivation to play the game. They were moderately motivated that digital games can help them to do more physical exercises than before. Furthermore, they have also motivated that digital games are valuable to their daily and weekly physical exercises. Noticeably, they agreed that digital games can improve their motivation to do physical exercises, followed by a claim that it can also be useful for doing physical exercises. Lastly, they had a high level of motivation to play digital game-based exercises again. Based on the findings from this, we found that the elderly participants were relatively motivated in playing digital game-based physical exercises. We also observed that the elderly participants' attitudes digital games after the gameplay had a positive relation to their motivation in the gameplay. It means that while their attitudes had changed more positive after the gameplay, the elderly participants were more motivated to play the game. The finding in this study is also supported by the whited paper by TNO and VitaValley (2015) in which it is stated that digital games are promising for fulfilling the motivational requirements for elderly people in exercising. Furthermore, the findings from the small-scale study conducted by Albaina et al. [31] supported that the elderly participants were motivated to exercise more by the digital game system. It is also in line with the findings from the studies reported in the literature review, including Brox et al. [32].

Elderly people's user experiences in the gameplay

For the elderly participants' in-game GEQ, we learned from the findings that their affection in the gameplay was quite positive, and they were relatively absorbed in the game. Furthermore, they were moderately interested and successful in playing the game. The participants reported that the game was not challenging enough for them. Significantly, they had almost no tension and negative affection in the gameplay. Based on the findings from the analysis of in-game GEQ, we observed that the elderly participants' in-game user experiences were moderately positive. Regarding the elderly participants' post-game GEQ, we found that the elderly participants had an average positive experience after they had played the game. Noticeably, they had almost no disorientation and tiredness after the gameplay. More importantly, their negative experiences after the gameplay were almost none. Overall, their post-game experiences were moderately positive. According to the findings from both in-game and post-game experiences. Although most of the elderly participants in this study never played digital games before, we observed that their experiences in playing the digital game-based physical exercises were relatively positive.

Findings from the post-study interview session

According to the findings from the post-gameplay interview questionnaires, we observed that the majority of elderly participants suggested that playing digital games can be an effective way of exercising and an alternative solution for their physical exercises. We also found that they were excited and interested in the gameplay. They highlighted that playing digital games have the poten-

tial to improve their socialization with others, as well as their health. Most of them claimed that although it was the first time for them, the game was simple and easy to play. Based on the findings from the post-study questionnaire and interview questions, we stated that the Skiing game is an easy and effective game for the Finnish elderly participants and digital game-based exercises are promising to be an alternative solution for them to exercise. In the existing literature, many studies also supported that digital games are promising to promote elderly people's physical activities in terms of physical exercises and rehabilitation [8].

Summary

In this study, we formulated three research questions and conducted a user experience test of the Skiing game with the Finnish elderly participants in Finland. The first research question asked if there is any difference in the Finnish elderly people's attitudes between physical exercises in general and digital game-based exercises. The findings showed that the Finnish elderly participants' attitudes towards physical exercises were significantly more positive than digital game-based exercises. They had a strong passion for doing regular physical exercises. Regarding their attitudes towards digital games, although they had a fairly negative attitude towards digital games, they became more positive towards digital game-based exercises after they had played the game. The second research question asked if the Finnish elderly people are motivated in playing digital game-based exercises. The findings showed that their motivation in playing digital game-based exercises was relatively high after the gameplay. They were quite motivated to play the game and they would like to play it again.

The last research question asked if there is a correlation between the Finnish elderly people's attitudes and motivation towards digital game-based exercise.

The findings showed that the Finnish elderly participants' motivation was higher to play the game while their attitudes towards digital games have become more positive than prior to the gameplay. Overall, their in-game and post-game user experiences were fairly positive although they did not have prior experiences in playing digital games. They showed their interests, enjoyment, and positive experiences in the gameplay. The findings from the interview session suggested that they recommended digital game-based exercises can be an alternative form of physical exercises. They highlighted that digital games can help them improve their physical activities, health, and socialization. Based on these findings, we conclude that digital games are a promising tool to be used as an effective solution to improve the Finnish elderly people's participation in regular physical exercises.

Conclusions

In this study, we reviewed a literature on elderly people's motivation and attitudes towards digital game-based exercises. Based on the findings from the literature, we formulated research questions and conducted a user experience test of the Skiing game with 21 Finnish elderly participants in Finland. We investigated the Finnish elderly participants' motivation and attitudes towards digital game-based exercises as well as their in-game and post-game user experiences. The findings show that the Finnish elderly participants' attitudes were more positive than their attitudes towards digital game-based exercises. Nevertheless, their attitudes have become more positive towards digital game-based exercises after they had played the game. Their in-game and post-game user experiences were moderately positive. The elderly participants commented that digital game-based exercise was interesting, exciting, and fun for them. The findings from this study support that digital game-based exercises can be an effective way of exercising for the Finnish elderly people. The discussion in this study can be insightful for researchers who are interested in adopting digital games to improve elderly people's participation in regular physical exercise activities.

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Lessons Learned from Two Usability Studies of Digital Skiing Game with Elderly People in Finland and Japan

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Abstract

Physical decline is associated with old age. Engagement in regular physical exercises can help elderly people improve their physical functionalities, as well as cognitive abilities. Among modern technologies, digital games have the potential to promote elderly people's engagement in physical exercises through fun and enjoyable gameplay. Although commercial digital games show promise, most of them are not designed for elderly people. The literature also suggests that more studies need to be undertaken to understand the usability and usefulness of digital games for elderly people. Hence, in this study, we designed and developed a digital game-based Skiing activity for elderly people. Then, we evaluated it with the Finnish and Japanese elderly participants in Finland and Japan to investigate their feedback towards the usability and usefulness of the game. The findings from both studies show that the Skiing game is an easy and user-friendly game for elderly people. While digital games are promising to be used as an alternative solution for promoting the Japanese elderly participant's physical activities, the Finnish elderly participants recommend to use it when they don't have access to non-digital physical exercises. The lessons learned from this study can help researchers, designers, and practitioners gain insights into game design and development for elderly people and their physical activities.

Keywords: *Digital games, Elderly People, Usability, User Experience, Human-Computer Interaction*

1. Introduction

Physical and functional decline is associated with ageing, and it is common in old age [1]. The American Psychological Association [2] states that most elderly people experience natural and normal age-related changes, including physical and cognitive decline, social disengagement, and health decline. According to Chappell and Cooke [3], physical health declines with increasing age, and it is also related to the likelihood of disability for elderly people. Manini [4] states that elderly people are at risk for a higher level of physical disabilities due to the ageing process and associated chronic diseases.

Engagement in regular physical exercise activities can improve elderly people's physical well-being, including physical fitness, functional ability, and independent lifestyle that are indicators for their quality of life [5]. According to Bherer, Erickson, and Liu-Ambrose [6], physical exercises are effective as a non-pharmaceutical intervention for elderly people to prevent cognitive decline and neurodegenerative disease (e.g. Alzheimer's disease). The benefits of

participation in regular physical exercises can not only prevent age-related diseases but also improve their quality of life [7].

With the help of the advent of technologies, people have been helping to promote elderly people' physical well-being in terms of their participation in physical exercises, rehabilitative training, and safety (e.g. fall prevention). Of these modern technologies, digital games are promising to promote elderly people's physical fitness and their participation in regular exercises through fun and engaging gameplay. Planinc et al. [8] state that digital game-based physical exercises can offer benefits for elderly people and enable them to be physically fit through motivating gameplay that leads to improvements in mobility. Beyond fun, recreational, and entertaining purposes, digital games are utilized to increase physical and cognitive functioning in elderly people [9, 10].

To date, there have been a number of scholarly studies that investigated the usability and usefulness of digital game-based exercises for elderly people. However, this research area is still new, compared with traditional Human-Computer Interaction and Usability for other age groups (e.g. young adults). Much of existing literature has stressed on the perceived health benefits of exergames for elderly people; however, little is known about the usability aspects of digital game-based exercises for them [9]. Whitlock, McLaughlin, and Allaire [11] also highlight that relatively little is known about digital game usability for elderly people. Planinc et al. [8] state that most commercially available games are not designed for elderly people, and there is a limited study on effective game design guidelines in digital games for elderly people. Gerling et al. [12] point out that there is a lack of comprehensive information regarding interaction design for elderly people in full-body motion-based games. To bridge the gaps between existing research and the use of digital games for elderly people, in this study, we aimed at understanding the usability, user experiences, and usefulness of digital games for elderly people in doing physical exercises.

The population in the European Union countries is rapidly ageing, and Finland is one of them [13]. The Finnish government and authorities have been promoting aged care, and the use of modern technologies (e.g. digital games) is one of the solutions in promoting the quality of life for elderly people in Finland [14]. In this study, we designed and developed a digital game-based exercise called the 'Skiing Game' to promote the Finnish elderly people' physical exercise activities. We evaluated the game with 21 Finnish elderly participants in Finland to understand their feedback towards the usability of the game, their user experiences, and the usefulness of the game. According to United Nations [15], Japan is one of the countries in the world that has the highest ageing population: 33 percent were aged 60 years or over in 2015. The Japanese government has used modern technologies that offer one approach to ease the increasing burden of aged care [16]. Among these technologies, healthcare practitioners and researchers in Japan have used digital games to promote elderly people's well-being [17]. The similar demographic challenge in Japan has drawn our attention and interest to investigate the Japanese elderly people's feedback towards the usability of digital game-based exercises and their user experiences in the gameplay. Thus, in this study, we collaborated with the Japanese organization (e.g. Sendai Wellbeing Center) and evaluated the game with 24 Japanese elderly participants in Japan. The main objectives of the study are stated as follow:

1. To investigate the Finnish and Japanese elderly people's feedback towards the usability of the Skiing game,
2. To investigate their in-game and post-game user experiences, and
3. To compare the differences between the Finnish and Japanese elderly people in responding towards the usability and usefulness of digital game-based exercises.

2. Background

2.1 Gamified Solutions in Healthcare

Gamified Solutions in Healthcare (GSH) is a collaborative project between the Turku University of Applied Sciences and the University of Turku in Finland [14]. The main objective of GSH is to provide gamified services for elderly people in Finland, including socialization, rehabilitation, entertainment, and counseling services. In this study, we only focused on the rehabilitation service, which utilizes digital games to enhance elderly people's physical exercise activities. To implement game-based rehabilitative services for elderly people, we applied the user-centered design

approach, which includes requirements gathering, design and analysis, prototyping, and evaluation [18]. For requirements gathering, we conducted a number of pre-studies that include an interview and observational studies with the Finnish elderly people at the elderly service homes in Finland [14, 19], a literature review [20, 21], reviewing existing games and technologies [22, 23], pilot user testing of commercial games and existing game from Puuha Group [24, 25], and forming a research agenda [19].

In pre-studies, we investigated the requirements of the Finnish elderly people in their daily activities, their acceptance of digital games for physical exercise, the usability and usefulness of commercial and existing games, and insightful design guidelines for future game development. Based on the findings from the pre-studies, we designed and developed the interactive Skiing game for elderly people. Then, we evaluated the game with the Finnish elderly participants at one of the elderly homes in Finland called 'Ruusukortteli (Rose Square)'. We also aimed to evaluate the game with the non-Finnish elderly participants outside of Finland to understand the feedback from the non-Finnish elderly people towards the game. Therefore, we collaborated with the as Sendai City Health Promotion Center and the Sendai-Finland Wellbeing Center in Japan. By conducting the cross-country evaluation of the game, we aimed at helping not only the Finnish elderly people but also other elderly groups living in foreign countries to promote their physical fitness and participation in regular physical exercises.

2.2 Related Studies

In recent years, people have used digital games for serious purposes other than fun, recreation, and entertainment activities [26]. For instance, digital games have been used for game-based learning, exergames, games for training, and gamification for business. In the context of healthcare, professionals and practitioners have regarded the potential of digital games for improving elderly people's physical exercises and rehabilitation [27]. Digital games have the potential to improve elderly people's physical well-being. It shows promises to improve elderly people's engagement and participation in regular exercise routines [28]. In addition, it has been used for rehabilitation [10] and fall prevention for elderly people [29].

According to Sato et al. [30], low adherence rate to physical exercises is a problem among elderly people. The researchers state that digital game-based exercises that involve physical motion of players are promising to keep them active [30]. They designed and implemented Kinect-based digital exercise system for elderly people to examine the effects of the game on elderly people and their health benefits such as muscle strength and body balance. They evaluated the game with 24 healthy community-dwelling elderly people, and their findings show that digital game-based exercises were effective in improving the muscular strength of lower extremities for elderly people. Pisan et al. [31] highlight that fall is one of the leading causes of injuries and disabilities for elderly people. They point out that physical exercises can reduce the potential risk of falling by 40%. However, elderly patient's adherence rate is low [31]. To promote elderly people's adherence rate to exercises, the researchers designed a digital game-based fall prevention training for elderly people and evaluated with them [31]. Their findings suggest that game-like exercises can result in increased adherence rate among elderly people to the physical exercise routines.

Chao et al. [32] conducted a review on a total of 22 empirical studies about digital games for elderly people's physical function, and their findings show that using digital games (e.g. Nintendo Wii) show promises as an alternative intervention to improve elderly people's physical function, cognition, and psychosocial well-being. Kaufman et al. [33] conducted a survey study with 463 adults, aged 55 years and above, to identify their gameplay experiences. The results show that the use of digital games can provide innovative and engaging activities for enhancing elderly people's aging processes. To date, there are a number of studies in academic research that reported the positive impacts of digital games on elderly people' physical well-being, including digital games for their physical therapy (e.g. stroke rehabilitation), functional tasks (e.g. game-based training for driving), activities of daily living (e.g. ADL training), and recreational activities (e.g. playing games).

Katajapuu et al. [37] evaluated digital memory game with a total 92 Japanese and Finnish elderly people in individual and group settings. Their findings show that the correlation between game difficulty and game enjoyment was found in the Finnish people but not in the Japanese population. They also reported cultural differences in digital game use and attitudes towards different digital brain exercise games (e.g. game preferences). Five exergames developed by researchers from Finland, Singapore, and Japan were tested with a total of 30 participants in

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Singapore in 2016 [38]. Their findings show that digital games are useful for elderly people's physical functioning.

2.3 Research Questions

The existing literature highlights the potential of the use of digital games for promoting elderly people's physical activities. However, there is only a few cross-country study about elderly people's perceptions of digital games and its usability and usefulness. More importantly, to our knowledge, a limited number of related studies can be found in the western and eastern context. To fill the gap in this research context, we expect to evaluate the usability, user experience, and usefulness of digital game-based exercises for elderly people in Finland and Japan. We formulated the following research question in our study:

Q1. What are the Finnish and Japanese elderly people' feedback towards the usability of the Skiing game and their user experiences in the gameplay?
Q2. What are the differences in user experiences between the Finnish and Japanese elderly people?
Q3. Are digital game-based exercises useful for both the Finnish and Japanese elderly people as an alternative way of exercising?

3. Methodology

In this study, we evaluated the Skiing game with 21 Finnish elderly participants in Turku, Finland [34, 35] and 24 Japanese elderly participants in Sendai, Japan [36]. In the following sub-sections, we describe the design and gameplay of the Skiing game, followed by the design and procedures of the Finnish and Japanese usability studies, and the questionnaires we used in both studies.

3.1 The Skiing Game

The main objective of the game is to promote the Finnish elderly people's regular exercise activities by using digital game-based exercises as an alternative solution. In the Skiing game, we used a simple, easy, and age-friendly game interface, familiar game context, and real-world game task. For the game context, we chose snowy mountains and a forest, which is inspired by the popular Finnish Lapland. For the gameplay, we used a popular cross-country Skiing activity (the double pole skiing technique), which is familiar to most of the Finnish elderly people. To play the game, a player needs to continuously move both hands forward and backward to ski in the game. In addition, a player simply needs to move his or her body to the left or right to avoid obstacles in the game. With regard to user's interaction experience, we used a motion-based interaction for elderly people by adopting Xtreme Reality Technology in the game (Extreme Reality technology, 2015). To implement the game, we used the Unity3D game engine with C# programming language. Figure 1 shows screenshots from the Skiing game.

Figure 1. The Screenshot of the Skiing Game

3.2 Finnish Usability Study

The test was conducted at the elderly service home '*Ruusukortteli'* in Finland, which supports elderly-care services such as social, recreational, and physical activities. Before we conducted the usability study, we consulted a physiotherapist from the elderly center regarding the recruitment, study design and procedures, and inclusion criteria for elderly participants. For the inclusion criteria, the elderly participants should be aged between 60 and 85 years, and they should have a sound and stable health condition and cognitive ability. Furthermore, the participants should be able to tolerate for at least 10 minutes to play a digital game-based exercise. They also should have a capability of standing and walking 10 meters independently. Lastly, they should have no neurological or cognitive deficits. We also requested the consent of the individual participant to be involved in the study. We recruited a total of 21 Finnish elderly participants at the elderly service home.

Then, we conducted the usability study for two days: day one with 17 participants and day-two with four participants respectively. Three researchers from the University of Turku and Turku University of Applied Sciences were involved in the study, and they provided guidance and help for the elderly participants in the gameplay, asked questionnaires, and conducted interviews. We recorded the whole usability study with a video recorder and a notebook to observe the elderly participants' behaviour, expression, feedback, and user experiences.

3.2.1 Design and Procedure

Firstly, the pre-study interview and gameplay sessions were undertaken at one of the therapy rooms, and the post-interview session was conducted at another therapy room at the elderly service home. Before an elderly participant played the game, a researcher asked the pre-game interview questions, which include demographics, physical activities, digital gameplay experiences, their attitudes towards digital games, and physical exercises. The pre-game interview session took about 10 minutes. Then, the elderly participant went through a tutorial session, which was guided by a researcher. Then, he or she played the game for a few times, depending on their request. The gameplay session took about 5 to 10 minutes, which can be different from one elderly participant to another.

After playing the game, a researcher asked the elderly participants the post-study interview questions, including in-game and post-game user experiences, the usability of the game, the perceived usefulness, and their ease-of-use of the game. Moreover, we also asked the general interview questions regarding their feedback, opinions, and attitudes towards the digital game-based exercises. The post-interview session took about 10 minutes. The whole usability study took about 30 minutes. The study was conducted in the Finnish language. Figure 2 shows a photo of an elderly participant playing the Skiing game.

Figure 2. The Finnish Usability Study of the Skiing Game

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3.2.2 Questionnaires

In this study, we used different questionnaires to investigate the elderly participants' user experiences in playing the Skiing game. Firstly, we developed the pre-gameplay interview questions to investigate the elderly participants' demographics, physical exercise activities, and their experiences in playing digital games. These questions are generally open-ended interview questions. Regarding the elderly participants' user experiences in the gameplay, we used Game Experience Questions (GEQ) developed by IJsselsteijn et al. [39, 40]. The GEQ contains two modules: in-game and post-game to assess players' user experiences. The in-game questionnaires are used to investigate players' experience while they are playing the game. It contains seven components, including competence, competence, sensory and imaginative immersion, flow, tension, challenge, negative effect, and positive effect. There are 14 items in the in-game module.

The Post-game GEQ questionnaire is used to find out how a player feels right after the gameplay. It includes four components such as positive and negative experiences, tiredness, and returning to reality respectively. There are 17 items in the post-game module. Both in-game and post-game GEQ questionnaires used a 5-point Likert scale from "Not at all (0)" to "Extremely (4)". To investigate the usability of Skiing game, we used the System Usability Scales (SUS), which is easy and simple to understand for elderly people, and based on ten-item scales that give the subjective assessments of the usability of a particular system [33, 34]. SUS questions also used the 5-point Likert scale from "Strongly disagree (1)" to "Strongly agree (5)". We modified the SUS questionnaires to be suited for the objective of the study. For general interview questions, we developed post-interview questions based on the Senior Technology Acceptance & Adoption Model (STAM) [41].The questions include four items that investigate elderly participants' perceived usefulness, perceived ease-of-use, gerontechnology self-efficacy, and gerontechnology anxiety. These post-gameplay interview questionnaires use open-ended questions.

3.3 Japanese Usability Study

We conducted a cross-country usability study of the Skiing game with 24 Japanese elderly in Japan [42], by collaborating with the Sendai City Health Promotion Center, which is a rehabilitation center, which provides rehabilitative training for the Japanese elderly people. They are interested in adopting digital game-based intervention for the Japanese elderly people to enhance their physical exercises. We recruited the Japanese elderly participants through an advertisement at the Sendai City Health Promotion Center, and physiotherapists and nurses helped us in the recruitment process. We used the same inclusion criteria for the Japanese elderly participants that were used in the Finnish study.

3.3.1 Design and Procedure

The entire usability study took two days. Firstly, 16 elderly participants played the game and answered the questionnaires on the day-one, followed by the remaining 8 elderly participants on the day-two. The study was undertaken by five researchers: three Japanese physiotherapists from the Sendai City Health Promotion center, one project officer from the Sendai-Finland Well-being center, and one Finnish researcher from the Turku University of Applied Sciences, Finland. In this study, the Japanese language was used to communicate with the elderly participants.

The study was taken place in three different rooms. At the station one (room one), a Japanese physiotherapist from the Sendai City Health promotion center conducted the pre-study interview, which includes the elderly's demographics, their physical exercise activities and experiences in playing digital games, and their consent. It took about 5-10 minutes. At the station two (room 2), two Japanese physiotherapists from Sendai City Health Promotion center helped the elderly participants to play the Skiing game. One therapist guided the elderly participants how to play the game, and the other monitored the participants to minimize their health risks. The total time for the station two took about 20 minutes. At the station three (room 3), a project officer from the Sendai-Finland Well-being center asked the questionnaires and post-interview questions in Japanese. One student from the Sendai National College of Technology helped us in recording the whole usability study with a video recorder. Figure 3 shows a Japanese elderly playing Skiing game.

Figure 3. The Japanese Usability Study of the Skiing Game

3.3.2 Questionnaires

In this Japanese study, we used a number of questionnaires to investigate the Japanese elderly's user experiences in playing the Finnish Skiing game. We used GEQ in-game and post-game questionnaires, SUS questionnaires, and post-gameplay interview questionnaires. We have used the same questionnaires and interview questions in the Finnish usability testing of the Skiing game.

4. Analysis and Findings

After collecting the data from the Finnish and Japanese usability studies of the Skiing game, we conducted both quantitative and qualitative analyses to investigate the elderly participants' responses and feedback towards the game. We also conducted a comparative study between the Finnish and Japanese elderly groups to understand their differences in user experiences and feedback towards the game. In this section, we reported the findings from both groups, followed by the comparison.

4.1 Pre-Gameplay Interview

Based on the findings from the pre-study interview sessions of the Finnish study, we found that 13 female (62%) and 8 male (38%) Finnish elderly people participated in the study. Their average age is 71 years. All of them are retirees, and they are the regular visitors to the elderly service home. The findings from the interview show that 19 out of 21 Finnish elderly participants are active in regular physical exercises, whereas only two participants were inactive doing physical activity due to their old age: 85 and 87 respectively. Among the active Finnish elderly participants, only six elderly participants usually do daily exercises for one to two hours, whereas other active participants spend 3-4 hours per week for physical exercises. They have a positive attitude towards physical exercises that it can benefit their physical health. For the Japanese study, we found there was an equal number of male and female Japanese elderly people participated (12 male and 12 female). The average age of the Japanese participants is 72 years. All participants visit the elderly center in Japan regularly, and they are active in doing regular exercises daily and weekly. They usually do physical exercises at least 5-7 hours per week. The findings from the pre-study interview show that the Japanese elderly participants have positive attitudes towards the benefits of physical exercises. The findings from two studies show that both elderly groups have similar positive attitudes towards doing physical exercises.

Regarding the elderly participants' prior experiences in playing digital games, 18 out of 21 Finnish elderly participants (86%) did not play digital games before. They had negative views and misconceptions towards digital games. For instance, 10 Finnish elderly participants mentioned that they are not interested in playing digital games, while two Finnish elderly participants stated that it is a waste of time. One Finnish participant revealed that playing digital games is only for young people. With regard to the Japanese elderly participants' prior experiences in playing digital games, half of the Japanese participants (12 out of 24) never played digital games before, whereas the other 12 Japanese participants have played digital games. In the Japanese study, six elderly participants who played digital games had negative attitudes towards digital games, claiming that

games are difficult to play and are not interesting. The other six Japanese participants who had prior gameplay experiences enjoyed playing digital games, and they recommended that playing digital games is fun, entertaining, and beneficial for their memory. For the Japanese elderly participants who never played digital games, they had neutral attitudes and showed they're interested in playing digital games. The findings show that 18 out of 24 Japanese elderly participants (75%) had a fairly positive attitude towards digital games Based on the findings from both studies, we found that the Finnish elderly participants had more negative attitudes towards digital games, compared with the Japanese elderly participants.

4.2 Systems Usability Scale

According to the findings from the Finnish usability study, we found that there was one Finnish participant (4.76%) who responded 'Best Imaginable' to the usability of the game, while 9 Finnish elderly participants (42.86%) rated the game as 'Excellent'. Moreover, there were 6 elderly participants (28.57%) who rated the game as "OK", while 2 of them (9.52%) rated "Poor" and one (4.76%) rated "Worst Imaginable". For acceptability ranges, 16 Finnish elderly participants (76.19%) rated "Acceptable", while 2 of them (9.52%) rated "Marginal" and 3 Finnish elderly participants (14.28%) responded as "Not Acceptable". For the Japanese usability study, we found that 8 out of 24 Japanese elderly participants (33.33%) responded that the game is "Excellent", while the other 8 participants (33.33%) rated as "Good". In addition, 7 out of 24 participants (29.1%) answered that the game is "OK", and one participant (4.17%) responded "Poor". Regarding acceptability ranges, 16 out of 24 participants (66.66%) responded that the game is acceptable, while 7 participants (29.1%) accepted the game as "Marginal". Only one participant (4.17) responded that the game is "not acceptable".

The majority of the participants from both elderly groups responded positively towards the game's usability. We analyzed the difference between two elderly groups, and the findings show that the feedback from both groups was not significantly different ($t(43) = -.27$, $p = 0.7$). Both elderly groups had similar positive feedback towards the usability of the Skiing game. The following Table 1 shows the SUS scores and scales of the participants from both elderly groups.

Table 1. System Usability Scale

SUS Adjective Scales	**No. of Finnish Participants (N=21)**	**No. of Japanese Participants (N=24)**	**SUS Score**	**Acceptability Ranges**
Best Imaginable	1 (4.76%)	-	90-100	Acceptable
Excellent	9 (42.86%)	8 (33.33%)	80-89	Acceptable
Good	6 (28.57%)	8 (33.33%)	63-79	Acceptable
OK	2 (9.52%)	7 (29.1%)	47-62	Marginal
Poor	2 (9.52%)	1 (4.17%)	25-46	Not Acceptable
Worst Imaginable	1 (4.76%)	-	0-24	Not Acceptable

4.3 In-game Experience

Regarding the Finnish and Japanese participants' in-game experiences, we found that both elderly groups had a relatively high mean score ($M >= 2.9$) in "Positive Affect" in the gameplay, whereas they had a low mean score ($M <= 0.5$) in "Negative Affect". Both groups had average mean scores ($M >= 2.0$) in "Flow", "Sensory and Imaginative Immersion", and "Competence". The gameplay was relatively challenging for the Japanese elderly participants ($M=2.4$), whereas it was not the case for the Finnish elderly participants ($M=1.2$). They had a noticeable small mean score number ($M <= 0.8$) for "Tension". The following table 2 shows the GEQ scores for both elderly groups.

Table 2. In-game GEQ Scores.

In-game GEQ (Gameplay)	Finnish Participants (N=21)		Japanese Participants (N=24)	
	Mean (M)	Standard Deviation (SD)	Mean (M)	Standard Deviation (SD)
Positive Affect	3.0	0.2	2.9	0.7
Negative Affect	0.1	0.1	0.4	0.4
Flow	2.6	0.3	3.0	1.0
Sensory and Imaginative Immersion	2.3	0.3	2.7	0.9
Competence	2.3	0.0	2.6	0.8
Challenge	1.2	0.2	2.4	1.0
Tension	0.1	0.1	0.8	0.7
* The highest Mean score (M) = 4.0				

Regarding the elderly participants' user experiences in playing the Skiing game, we compared the results of in-game positive affect between the Finnish and Japanese elderly participants, and the findings show that there is no significant difference between them ($t(43) = 0.433$, $p = 0.7$). It means that both elderly groups had similar positive affection in playing the game. For the component 'Competence', we found that there was no statistically significant difference between the Finnish and Japanese elderly participants ($t(43) = -1.1$, $p = 0.8$). It means that both elderly groups had a successful experience to play the Skiing game. Furthermore, we observed that the components 'Flow' ($t(43) = -1.29$, $p = 0.2$) and 'Sensory and Imaginative Immersion' ($t(33.8) = -1.1$, $p = 0.3$) were not significant between the Finnish and Japanese elderly groups. The results indicate that both groups were moderately absorbed and interested in the gameplay.

In contrast, we found that the elderly participants' negative affection in the gameplay was significantly different ($t(43) = -2.0$, $p = 0.05$), and it shows that the Japanese elderly participants had slightly more negative experiences, compared with the Finnish elderly participants. We also observed the similar result in the elderly participants' level of tension in the gameplay ($t(27.5) = -4.43$, $p = 0.0$). It indicates that the Japanese elderly participants had a slightly higher level of tension, compared with the Finnish elderly participants. Furthermore, we found that the Skiing gameplay was more challenging for the Japanese elderly participants than the Finnish elderly participants ($t(43) = -4.24$, $p = 0.0$).

4.4 Post-game Experience

For their post-game experiences, we found that both elderly groups had an average score in "Positive Experience" ($M >= 2.0$), whereas they had a considerably low mean score ($M <= 0.9$) in "Negative Experience". They had a low mean score in "Returning to Reality" ($M <= 0.8$), while both groups also had a very low mean score in "Tiredness" ($M <= 0.4$). The following Table 3 shows the GEQ Post-game scores of both elderly groups.

Table 3. Post-game GEQ Scores.

Post-game GEQ (After Gameplay)	Finnish Participants (N=21)		Japanese Participants (N=24)	
	Mean (M)	Standard Deviation (SD)	Mean (M)	Standard Deviation (SD)
Positive Experience	2.0	0.3	2.1	1.0
Negative Experience	0.1	0.1	0.9	0.4
Returning to Reality	0.8	0.5	0.5	0.4
Tiredness	0.1	0.1	0.4	0.6
* The highest Mean score (M) = 4.0				

Regarding the differences in post-game user experiences for both elderly groups, we found that there was no significantly significant difference in positive experience ($t(43) = -0.25$, $p = 0.8$), indicating that both elderly groups had a positive gameplay experience after they had played the Skiing game. Similarly, their experiences to 'Returning to Reality' were not significantly different

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(t (43) = -0.33, p = 0.7). It indicates that both groups had no disorientation after the gameplay. In contrast, we found that there was a significant difference in their negative experiences (t (34.5) = -4.7, p =0.0). It means that the Japanese elderly participants had slightly more negative experiences in the gameplay, compared with the Finnish elderly participants. The similar results can be also found in 'Tiredness' (t (38) = -2.57, p = 0.01), indicating that the Japanese elderly participants were slightly more tired in the gameplay than the Finnish elderly participants.

4.5 Post-Gameplay Interview

Regarding the Finnish and Japanese participants' gameplay experiences to play the Skiing game, we conducted the post-gameplay interview sessions in both studies. We compiled the participants' responses and created different categories for similar responses and feedback. Then, we analyzed the qualitative data from four different data sources, including video observations, note-taking, and interview sessions. Firstly, in each analysis, we coded and analyzed the data, followed by categorization. Then, we de-categorized them if necessary until we identified the important findings. We created different categories, including game context, user interface, gameplay, feedback, user experience, and interaction. Table 4 shows the selected quotes from the participants that we used for the analysis.

According to the categories created based on the participants' feedback towards the game system, both elderly groups recommended that they prefer digital game context, which is designed to be a real-world environment in the virtual world. For instance, in the Skiing game, a snow resort theme as a game context was designed and simulated especially for the Finnish players so that it can remind them of skiing activity in Finland. The findings from the qualitative interview also showed that the participants' responses to the game context were positive. With regard to the usability of the game, some elderly participants from both studies suggested that visual cues can be helpful for them due to their poor eyesight, as well as their lack of experiences in the digital gameplay. Furthermore, they recommended that using voice-based instructions in their own languages will be helpful for them to play more easily. Both Finnish and Japanese participants suggested that they prefer to play real-world activities and sport based gameplay such as cycling, tennis, golf, and driving.

The findings from the participants' responses, we found that negative feedback from the game can discourage them. For instance, the findings from the observations in both studies showed that the elderly participants were frustrated in the gameplay whenever they (the virtual character) fell down in the game. Moreover, in the interview session, they mentioned that negative reactions in the game can lessen their level of confidence to continue playing. We also found from the interview studies that the elderly participants revealed their concern that they may fall down in the gameplay unless they can balance their body during the gameplay. In addition, some participants revealed that they had a motion sickness to a certain extent while playing the game. We also notice that especially for the novice elderly players, they prefer the simple gameplay rather cognitively challenging activities in the game. The elderly participants suggested that low achievement in the gameplay for their first time can lead them to the abandonment of the gameplay in the future. Lastly, they recommended that playing digital games with controller-free interaction was easy and effective to play the game.

Table 4. Participants' Quotes.

Category	Finnish Participants' Quotes	Japanese Participants' Quotes
Game Context	"this game reminds me of Lapland (Northern region of Finland) and it was fun to do skiing activity in the game" (FP1)	"It was enjoyable to play a game-based skiing activity" "I felt like I was in a skiing resort" (JP3)
	"That real-world environment games are fun to play like cycling in nature" "I would like to try different types of games playing in the real-world" (FP9)	"Activity-based games are interesting" "I like to try fishing game, football, cycling, driving, etc." (JP24)
User Interface	"My eye sights are not so good. So I can't see clearly sometimes" "It will be better if the trunks in the game are highlighted so that I can avoid them". "I think the game can provide voice instruction in the Finnish language to	"I hit and fall many times in the game because I don't know that I have to avoid the fallen trunks in the game". "My eyes are tired to pay attention to this" (JP14)

	easily understand what to do" (FP8)	
Gameplay	"I like physical activities" "When I was young, I used to do skiing but not now because of my health" "It's fun to play that kind of game" (FP1)	"I would like to try other types of games like cycling, fishing, tennis, golf, etc. " (JP10)
	"Skiing is fun. It reminds me of old days" "I like to try more" (FP21)	"Skiing activity is popular in Japan" "It's exciting to play it" (JP19)
Feedback	"Whenever I fall down in the game, I was discouraged" "Instead of falling down, it should show something…[sic]" (FP10)	"I am afraid that I would fall down in the real-world when I hit the fallen trunk in the game" (JP1)
User Experiences	"I was nervous that I would fall down while playing the game"(FP6)	"The body balance is important. Otherwise, I might fall when I am off-balance in the game" (JP1)
	"I felt frustrated that I hit and fall in the game" "It discouraged me" "Other than that, it was a fun experience" (FP11)	"It was quite difficult to go upward the mountains in the game" "I felt a bit uneasy to move faster". (JP7)
	"I felt a bit giddy in the gameplay" "I am afraid of falling down if I feel motion sickness" (FP20)	"If I feel a bit shaky to see the screen, I can't see properly" (JP17)
	"It was my first-time experience" "When many fallen trunks are coming towards me, I don't know how to avoid them". (FP12)	"I tried hard to understand what to do with the gameplay" "It's a bit hard at first, but slowly I got an idea what to do next". (JP5)
	"For the first time playing digital games, I felt a bit depressed to have low scores [sic]" (FP2)	"I think my performance was poor in the gameplay because I am old [sic]" (JP8)
Interaction	"I used game controllers with buttons and they were confusing" "It's easier for me to use controller-free interaction". (FP17)	"I like to play the game without using any controllers" (JP23)
	"I think it's more natural to play the game with no buttons…[sic]" (FP6)	"Movements are easier when there is no physical controller to hold by hands" (JP13)

Regarding the participants' attitudes towards playing digital games after they had played the Skiing game, we asked the interview questions to both elderly groups. Based on the findings from the analysis of their responses, we found that both elderly groups had positive attitudes towards digital games after the gameplay. For the Finnish elderly participants, the majority of them (81%) suggested that playing digital games was fun, easy, and entertaining. 57% of the Finnish elderly participants agreed that playing digital games can be beneficial for them. 71% of the Finnish elderly participants mentioned that they would like to play it again, as well as to try other types of digital games. 67% of them revealed that they will play it regularly, while others claimed that they may not have adequate resources to play it regularly.

For the Japanese elderly participants, 96% of them claimed that playing digital games is fun, easy, and entertaining. 83% of them suggested that playing digital games can be beneficial for their physical health. 91% of them suggested that they would like to play it again in the future, and try various digital games. Similarly, 91% of the Japanese elderly participants mentioned that they will play digital games regularly if they have adequate resources in terms of devices and manpower (e.g. therapists). Lastly, we asked whether playing digital games can be an alternative solution for them to do physical exercises regularly. We found that 66% of the Finnish elderly participants suggested that playing digital games can be a second priority for them because they think that regular physical exercises are more important. They also mentioned that digital game-based solution will be useful when they do not have access to regular physical exercises. For the Japanese elderly participants, 83% of them suggested that playing digital games can be an alternative solution for them because it can provide an enjoyable way of exercising.

5. Discussion

Based on the findings from the analysis of data from both studies, we observed similarities between the Finnish and Japanese elderly participants. For instance, we found that both Finnish and Japanese elderly participants are active in doing physical exercises. Moreover, they are aware of the benefits of doing regular physical exercises activities. They have similar positive attitudes towards physical exercises. Regarding their prior experiences in playing digital games, the Japanese elderly participants had more experiences than the Finnish counterparts. In addition, we found from the pre-interview studies that prior to the gameplay session, the Japanese elderly participants had more positive attitudes towards playing digital games, while the Finnish elderly participants had relatively negative attitudes towards playing digital games. Regarding the participants' responses to the usability of the Skiing game, we found that elderly groups responded quite positively, and there is no difference between two groups. Similarly, both elderly groups had relatively positive in-game and post-game experiences except the fact that the Finnish elderly participants had slightly more positive experiences, compared with the Japanese counterparts.

With regard to the post-gameplay session, we found that both elderly groups had changed their attitudes towards the game more positively. Compared with the Finnish counterparts, the findings show that the Japanese elderly participants have more positive attitudes towards playing digital games after the gameplay. The findings also show that the Japanese elderly participants are more active to play digital games in the future. They recommended that playing digital games can be an alternative solution for them to do physical exercises. They also recommended that playing digital games can be beneficial for their physical health. In contrast, the Finnish elderly participants suggested that playing digital games can be an alternative solution for them when they do not have access to primary physical exercises, which they regularly do at elderly service homes (e.g. Physiotherapy exercises).

Based on the findings from both Finnish and Japanese usability studies of the Skiing game, we answered the research question 1 (Q1) that the Skiing game is an easy, usable, and user-friendly game for the Finnish and Japanese elderly people. With regard to their user experiences, both elderly groups had a relatively positive experience in the gameplay. Furthermore, the elderly participants who did not have prior experiences in playing digital games have become interested in playing digital games. Their attitudes towards digital games have changed positively after the gameplay. For the research question 2 (Q2), although the Finnish elderly participants had more positive experience in the gameplay, the Japanese elderly people showed more interest in playing digital games as an exercise activity in the future. Regarding the research question 3 (Q3), the Japanese elderly people are more positive towards using digital game-based exercises as an alternative solution, whereas the Finnish elderly participants recommend to use it as a second option when they don't have access to conventional physical exercises.

From both Finnish and Japanese usability studies, we have learned a number of lessons including the usability of the game, game design, user experiences, and interaction experiences. Based on the findings from the qualitative analysis of the participants' responses and feedback towards the game, we highlighted the following usability lessons learned from both studies. Frist of all, regarding game context and gameplay, we learned that the elderly participants enjoy playing digital games, which are simulated as a real-world environment (e.g. Skiing resort). We also learned that the elderly participants enjoyed playing real-world physical activities in the game (e.g. Skiing activity). Secondly, with regard to game interface, we learned that visual cues are important to be provided in the game system so that elderly participants can interact with the game more effectively. We also noted that the elderly participants also preferred voice-based instruction in the game. Thirdly, regarding game feedback, the findings suggested that the elderly participants preferred positive feedback provided by the game.

One of the important lessons learned about players' experiences is that the elderly participants were afraid of getting injuries while playing the game. Thus, we learned that minimizing their physical risks in the gameplay is important. In addition, we also learned that if the elderly participants encountered frustration in the gameplay, it would lead to their discouragement to continue playing the game. Therefore, we learned that minimizing their frustration in the gameplay is also an important factor to be taken into account in the game design. We also learned that the cognitive complexities in the game are not suitable for the elderly participants, especially for their first time experiences. We also need to be aware of the elderly participants' motion sickness in the game, and it should be taken into consideration while designing digital games especially for elderly players. We also learned that creating a sense of achievements for novice elderly participants can encourage them to play the game in the future. Lastly, regarding their interaction

experiences, we learned that the elderly participants prefer using controller-free interaction that can make them easy to play the game. The following Table 5 lists the usability lessons that we learned from both Finnish and Japanese usability studies.

In summary, from both the Finnish and Japanese usability studies of the Skiing game, we report that digital games are useful as an alternative solution for promoting elderly people's physical exercise activities. This finding also supports the existing literature [10, 11, and 12]. Although the Skiing game was designed for the Finnish elderly people, it has been accepted by the non-Finnish elderly people as a form of exercise activity. The findings also show that user-friendly digital games can positively change non-gamers elderly people' perceptions of digital games. The findings from this study can help researchers and practitioners gain insights into using digital games for promoting elderly people's physical activities. It can also help game designers and developers gain insights into usability guidelines for designing digital games for elderly people.

Table 5. Usability Lessons.

Category	Lessons Learned
Game Context	1. Real-world game context simulated in the game should be taken into account in the game design.
Game Play	2. Real-world activities designed in the game are suitable for elderly players.
Game Feedback	3. Positive game feedback should be provided in a game.
User Experiences	4. It is important to minimize physical risks of elderly players in the gameplay.
	5. It is important to minimize elderly players' frustration in the gameplay.
	6. It is important to minimize cognitive complexities in the game, especially for novice elderly players.
	7. It is important to minimize elderly players' motion sickness in the gameplay.
	8. Creating a sense of achievements for novice elderly players is important.
User Interface	9. Providing visual cues and voice-based instructions should be taken into consideration in game design for elderly players.
	10. Controller-free interaction is easy and effective for elderly players.

6. Conclusions

Finland in the European Union has been facing a challenge of demographic change and so is Japan in East Asia. The literature suggests that digital games show promises for elderly people's physical exercise activities. However, some researchers argue that more studies need to be done in order to investigate the usability and usefulness of digital games for elderly people. Hence in this study, we conducted the usability evaluation of the "*Skiing game*" with the Finnish elderly people in Finland to understand their feedback towards the game. We also conducted a cross-country usability evaluation of the game with 24 Japanese elderly participants in Japan to understand the non-Finnish elderly people' perceptions of the usability of the game. We conducted pre-study, observation in the gameplay, and post-study by using SUS and GEQ questionnaires, as well as interview questions to understand the elderly participants' responses and feedback towards the usability of the game and their gameplay experiences.

Based on the findings from both studies, we found that both elderly groups had relatively positive experiences in in-game and post-game, as well as their responses towards the usability of the game is noticeably positive. The Finnish elderly participants had a relatively negative attitude towards digital games prior to their gameplay, whereas the Japanese elderly participants were fairly positive to digital games. After the gameplay, both elderly groups' attitudes towards digital games had become positive, while the Japanese elderly participants showed more interests and positive attitudes towards digital games. Furthermore, the Japanese elderly participants recommended that playing digital games can be an alternative solution for them to do physical exercises, and it can be beneficial to their physical health. For the Finnish elderly participants, they recommended that playing digital games can be an alternative solution for them when they don't have access to conventional physical exercises. We also learned a number of usability lessons from

both studies, and we reported them in this study for researchers and practitioners to take into consideration when they design and develop digital games for elderly people.

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