The Computer Games Journal (2020) 9:163–188
https://doi.org/10.1007/s40869-020-00100-w

# A Case Study on Co-designing Digital Games with Older Adults and Children: Game Elements, Assets, and Challenges

**Martti Havukainen[1] · Teemu H. Laine[2] · Timo Martikainen[1] · Erkki Sutinen[3]**

Published online: 2 April 2020


**Abstract**
Digital games have traditionally been targeted at younger generations, although the proportion of older adult players is increasing. However, the design processes of digital games often do not consider the special needs of older adults. Co-design is a potential method to address this, but there is little research on co-designing games with older adults. In our study, we proposed a co-design process model that considers the intergenerational perspective. Using this model, eight older adults (two males and six females aged 47–80) and 22 sixth graders (11 males and 11 females aged 12–13) co-designed a digital game. The content of the game was based on old concepts used by the designers during their childhood. Similarly, game content involving new words and concepts were produced by the sixth graders. We collected data using semi-structured interviews and observations during the co-design process over a period of 24 months and then processed the data using grounded theory. The results indicated that the older adults identified seven game elements as essential to make games fun—appearance and aesthetics, competition, manageability of gameplay, social impact, familiarity, unpredictability, and intergenerational gameplay. Furthermore, we identified six assets that older adults have as game co-designers and five challenges that co-designing games with older adults may entail.

✉ Martti Havukainen
martti@havukainen.com

Teemu H. Laine
teemu@ubilife.net

Timo Martikainen
timo.martikainen@uef.fi

Erkki Sutinen
erkki.sutinen@utu.fi

[1] University of Eastern Finland, Joensuu, Finland

[2] Luleå University of Technology, Skellefteå, Sweden

[3] University of Turku, Turku, Finland

**Keywords** Digital game · Older adults · Co-design · Game design

## 1 Introduction

Modern society has seen unprecedented growth in the population of older adults. This is the result of the combination of the post-war baby boom, decreasing fertility rates, and increasing life expectancy (Bloom and Luca 2016). In 2017, the number of people aged 65 and over was nearly 600 million or 8.5% of the total population, and the older adult population is expected to reach nearly 1.6 billion by 2050 (He et al. 2016). In developed regions, such as Europe, North America, and East Asia, the proportion of people aged 65 and over is expected to increase from roughly 14% (2015) to 21–28% or even more (He et al. 2016). This tremendous demographic shift introduces various challenges related to, for example, health care, economics, industry, and education.

The World Health Organization (2002) considers older adults to include people aged 65 years or over in developed countries and people aged 60 years or over in developing countries. Digital technology has become a part of their day-to-day activities. Everyday objects, such as telephones, televisions, and cars, are digital and therefore require that new skills be mastered. A part of this digitalization is games, which are being increasingly consumed by older adults. Therefore, there is intense research going on at the intersection of ageing and gaming. There has been various reviews published by scholars focusing on the various fields which are using serious games as a means of improving cognition, rehabilitation, social life, physical activity, engagement, health and wellbeing (Larsen et al. 2013; Marston et al. 2016a; Marston and Hall 2016; Marston and Smith 2012; Wiemeyer and Kliem 2012), and the effects (e.g., physical, cognitive, social) of digital games on older adults (Hall et al. 2012; Marston et al. 2015; McLaughlin et al. 2012; Zhang and Kaufman 2015). Researchers have also explored the process of designing digital games for older adults (Gerling et al. 2012; Ijsselsteijn et al. 2007; Marston 2013a), which connects to the interaction and engagement of gamers and non-gamers alike (Marston 2013b; Marston et al. 2016b). However, the perspective of older adults as game co-designers has received less attention.

Digital games have traditionally been targeted at younger generations, although the proportion of older adults who play games has become significant in many countries. According to a report by the Interactive Software Federation of Europe (2018), 44% and 40% of adults aged 45–64 in France and Germany, respectively, play games. In the United States, the number of gamers among adults aged 50 and over was 38% in 2016 (Anderson 2016). Professional game designers have synthesized and summarized their years of game design experience in various game design books that provide guidance for the game design process. For example, Schell (2014) proposes 100 lenses or perspectives through which game designers can create and analyze their games. Salen and Zimmerman (2003) assume a more scholarly approach, covering concepts, strategies and methodologies related to games and game design. Although game design books like these can provide useful guidance for commercial game design, they fail to consider the special needs of older adults.

Co-design has emerged as a popular method for service and product design that invites end users to participate in the design process with their ideas and expertise. Based on a literature review and an analysis of three case studies, Steen et al. (2011) suggest a number of ways that co-design benefits projects, including but not limited to better ideas in the design process, better knowledge of the target users' needs, better fit of the end result to the target users' needs, greater user satisfaction and loyalty, and reduced time and cost of development. There also exists a body of literature on co-designing products and services with older adults in several areas, including nursing, cognitive well-being, and everyday life (How et al. 2017; Lehto and Rantanen 2017; Marston 2013a; McGee-Lennon et al. 2012; Treadaway and Kenning 2016). However, there is a paucity of research relating to co-design and co-production between older adults within game design teams and acknowledging the various roles and responsibilities that each actor contributes to a project. Rather than thinking of ageing as a challenge in designing digital games, a person's life experiences can be regarded as an asset in co-designing them.

This paper documents a key part of a more comprehensive process of designing digital games with and for older adults. The focus is on identifying what game elements older adults appreciate in digital games and on the assets of older adults as game co-designers. Additionally, we identify challenges that might occur when co-designing games with older adults. In our case, a group of older adults co-designed a multiplayer game—*Onnen tähti*—to learn new words and to maintain familiar but outdated words. To add an intergenerational angle to the study, we involved children in the co-design process as experts of modern vocabulary. Additionally, an information technology student was involved as a programmer of the game prototype. To the best of our knowledge, in addition to presenting a multiple-choice game artifact for learning and practicing the meanings of old and new Finnish words, this study is the first account of investigating co-designing of digital games with older adults with a focus on game elements that older adults consider important, the assets of older adults as game co-designers, and the challenges that may emerge when co-designing games with older adults. The results therefore complement the existing body of research on co-designing digital games with older adults.

## 2 Background

### 2.1 Ageing, Cognitive Abilities, and Digital Environments

The term *older adult* is used to describe individuals aged 65 or over in developed countries and individuals aged 60 or over in developing countries (World Health Organization 2002). According to a United Nations report (2017), the world's population of those over 60 was 962 million in 2017, more than twice the 1980 figure of 382 million. The adult population continues to grow older rapidly, as fertility rates have fallen to very low levels in most of the world's developed regions and people live longer (United Nations 2017). Therefore, the global population of those over 60 is expected to double again and reach 2.1 billion by 2050 (United Nations 2017).

This demographic shift is significant because of the health-related challenges caused by ageing.

Although many older adults are in good health, they are likely to experience changes in cognitive and physical abilities as the years go by. A decline in cognitive ability begins to manifest after the age of 50 in terms of some functions and after the age of 60 or 70 in terms of others. Ageing brings cognitive changes, particularly in relation to attention and memory. Other cognitive skills, such as language processing, decision making, and perception, are also affected (Glisky 2007). However, there is great variability in the rate of change among older adults (Glisky 2007; Woods 2004).

As digitization affects many aspects of our lives today, there is a need to adjust the digital environment of older adults. Scialfa and Fernie (2006) describe an adaptive technology that accommodates physical, cognitive, and sensory impairments, thus providing increased accessibility to services. Yamamoto et al. (2015) detail the possibilities of Internet-connected assistive systems to support older adults in managing their daily lives, thus reducing the need for caregiver support. Such adaptive and assistive solutions often utilize various techniques to customize the user experience, including but not limited to adjusting screen size, font size, and contrast in graphics. Moreover, older adults' declining fine motor skills necessitate special methods for interaction and input, such as larger targets to press/tap and speech-to-text functionality for textual input. One way to develop these kinds of adaptive technologies is to combine research results from late adulthood psychology, collected test experiences, and design guidelines regarding the usability and user experience of technological solutions (Scialfa and Fernie 2006).

Stine-Morrow and Basak (2011) have reviewed cognitive interventions among older adults. Video games and other computer-based activities have been researched as possible tools to affect cognitive abilities. The authors demonstrate that playing arcade-type video games (e.g. Pacman, Donkey Kong, Tetris) helped improve response and reaction times, whereas playing a complex real-time strategy game (e.g. Rise of Nations) helped improve higher-level cognition skills (task switching, working memory, visual short-term memory, and reasoning). Stine-Morrow and Basak (2011) state that according to cognitive neuroscience and the behavioral data on ability training, the mind and the brain are well-suited to learn individual skills throughout a life span. A high level of mental fitness is possible longer into the life span than is often believed, but this depends on the coordinated enhancement of physical fitness, intellectual stimulation, and strong social networks (Stine-Morrow and Basak 2011).

### 2.2 Older Adults and Games

Digital games can be found on almost any computing platform, including computers, mobile phones, tablets, televisions, and smart watches. Most digital games, especially console-based ones, have been designed for boys and men (Marston 2010). Indeed, in the otherwise rich gaming sector, there are only a few digital games designed especially for older adults. Several examples can be found in

various reviews focusing on therapeutic, preventive, and rehabilitative games—both commercial and academic—for older adults (Bleakley et al. 2015; Bonnechère et al. 2016; Choi et al. 2017; Griffiths et al. 2017; Hall et al. 2012; Marston et al. 2016a; Marston and Smith 2012; Miller et al. 2014; Wiemeyer and Kliem 2012). Yet, games are enjoyed by people regardless of their age. Research shows that older adults use games mostly as a pastime activity (Boyle et al. 2012; Kankainen and Lehtinen 2011); however, three studies report that older adults are also interested in playing games when they see the activity as a low-cost option to help them maintain their health and improve their quality of life (Brown 2012; Gerling et al. 2012; Lim et al. 2012). Among the possible reasons why older adults are attracted by games are their entertainment elements and the strong social dimension that enables casual conversation during gameplay. Moreover, when the digital game is of intergenerational nature, it may help reinforce family bonds, enhance reciprocal learning, increase understanding of the other generation, and reduce social anxiety (de la Hera et al. 2017).

Digital games can help combat the limitations associated with ageing by encouraging older adults to exercise physically and mentally, thus delaying the occurrence of diseases and improving their quality of life (Cota and Ishitani 2015). There are also more positive aspects reported by other studies. Chen et al. (2012) state that certain games may reduce the cognitive decline associated with ageing, such as loss of memory and lack of attention. The use of specific games can help in diagnosing and treating neuropsychological diseases, and in some cases, they may be more effective than traditional methods in treating psychosocial problems (Cota and Ishitani 2015). However, there are some concerns about whether cognitive training games are effective. Simons et al. (2016) point out the ongoing debate over the efficacy of brain-training games and, having analyzed the existing literature on brain-training interventions, suggest that when used extensively these games may improve performance on the trained tasks but have less effect on improving overall everyday cognitive performance.

### 2.3 Challenges in Designing Games for Older Adults

Designing games for older adults requires a different approach than designing commercial games due to the special demands of older adults as target players. Traditional game design methods do not consider the special ageing-related needs of older adults (Gerling et al. 2012). Table 1 summarizes the challenges and proposed solutions based on our literature review. Utilizing these and other design guidelines can help in creating games that are more suitable for older adults. Moreover, by co-designing games *with* older adults, we can benefit from their unique assets vis-à-vis the design process, thus further ensuring the viability of the results.

### 2.4 Co-designing with Older Adults

Co-design is the process of designing artefacts (e.g., products or services) together with the intended end users. It has been used in many areas related to

**Table 1** Challenges associated with designing games for older adults

| Challenge | Solutions |
|---|---|
| Problem solving and reasoning | Adjustable, appropriate cognitive challenges (Flores et al. 2008; Weisman 1983) |
| Attention span and memory | Simple and intuitive screens that decrease memory load (Flores et al. 2008; Gamberini et al. 2006; Ijsselsteijn et al. 2007); easy-to-understand game actions that are related to the real world (Gerling et al. 2012; Marston 2013a) |
| Visual processing | Large and well-defined visual symbols (Weisman 1983); allow the user to control font, color, and contrast (Ijsselsteijn et al. 2007) |
| Auditory processing | Clear auditory feedback (Marston 2013a; Weisman 1983); use lower frequency tones and provide information through multiple modalities (Ijsselsteijn et al. 2007) |
| Unfamiliarity with technology | Provide immediate, encouraging, and positive feedback on learning goals and enough time to learn basic skills (Flores et al. 2008; Gamberini et al. 2006; Ijsselsteijn et al. 2007; Marston 2013a) |
| Unfamiliarity with gaming | Provide clear information about game restrictions, requirements, and objectives (Gerling et al. 2012); enable user to experiment with the game system (Marston 2013a) |
| Motor skills (e.g., reaction time, coordination, balance) | Avoid small targets and moving interfaces (Ijsselsteijn et al. 2007); adjust the game to decreased sensory acuity and slower responses (Flores et al. 2008); provide alternate control mechanisms (Gerling et al. 2012; Marston 2013a); simple and intuitive interaction (Marston 2013a) |
| Capturing and maintaining interest | Provide content that is purposeful and interesting to users (Flores et al. 2008; Ijsselsteijn et al. 2007; Marston 2013a); use appropriate game genre (Flores et al. 2008); enable user-created content (Marston 2013a) |

older adults, such as prevention, rehabilitation, and the maintenance of independence, physical health, and cognitive ability(How et al. 2017; Lehto and Rantanen 2017; McGee-Lennon et al. 2012; Treadaway and Kenning 2016). The reasons for using co-design or user-centered design are to achieve higher quality artefacts, a better fit between the artefact's functionalities and target users' needs, and improved user satisfaction (Wintermans et al. 2017). This is particularly important when designing games for older adults, as their requirements differ from those of younger players (see Sect. 2.3).

Several previous studies demonstrate the successful co-design of products and services for older adults. For example, a recent systematic literature review by Merkel and Kucharski (2019) presents an analysis of 26 studies that use co-design (participatory design) in the field of gerontechnology, suggesting that co-design is suitable for finding novel ways of using existing technology, for developing new devices for older adults, and for testing or modifying design prototypes. The authors recommend the co-design process should follow a comprehensive strategy starting with analyzing users' needs and ending with evaluating the outcome. According to Davidson and Jensen (2013), the input of older adults is particularly valuable in the ideation phase of the co-design process. The authors

found that older adults showed enthusiasm when co-designing mobile healthcare applications.

Co-design has also been employed in a few cases to design games with older adults. Vanden Abeele and Van Rompaey (2006) introduce a human-centered method for innovating gameplay based on ethnographic principles and participatory design. The methodology was applied in a project to design game concepts with older adults. The authors started by observing older adults in their everyday lives in order to identify what positive experiences they encounter; the game design process was then based on these experiences. Loos et al. (2019) present a literature review of eight studies focusing on co-designing intergenerational digital games and give seven recommendations to facilitate the co-design of such games. Romero and Ouellet (2016) state that game co-design is a powerful learning activity that could benefit the learning processes of users from childhood to older age. Veloso and Costa (2015) investigate co-designing to identify suitable social networking game components for older adults. Their findings suggest that collaboration is a particularly important factor for older adults as game co-designers.

## 3 Research Design

### 3.1 Problem Statement and Research Questions

*Problem Statement*: Older adults have time and life experience, but their assets are undervalued and therefore underused. This fact applies in relation to digital game design that requires the integration of content and technology. The challenge is to identify the ways in which older adults can use their unique assets to be active, contributing participants in the game design process rather than merely analyzing the usefulness of existing games in solving various life and entertainment challenges of older adults.

To address the problem, we have formulated the following *research questions*:

1. What game elements are important for older adults as co-designers of digital games?
2. What are the assets of older adults in a digital game co-design process?
3. What challenges can be encountered when co-designing digital games with older adults?

### 3.2 Research Method

In this study, we utilize grounded theory (GT) to analyze the data collected via semi-structured interviews and observations during a game co-design process. GT gives an opportunity to create a theory based on the collected data. A key feature of GT is continuous comparison; different comments are compared, data on the same comment are compared at different times, different situations are compared, data are

divided into categories that are being generated throughout the process, and the categories are likewise compared to each other.

Our study investigates an iterative process of co-designing a game and a game design evaluation, both of which occur with the game design team comprising older adults. We use the three-stage format of GT proposed by Koskela (2011); see Table 2.

Open coding in our research means finding concepts from the data and naming them. Examples of these concepts are the life experience based on which one can create content for a game, the previous experience of playing games, and the desire to create games and meaningful content for them. In the axial coding step, we created categories and subcategories based on the codes, such as sociality, previous gaming experience, and the ability to create game content based on life experience. In the selective coding step, we created main categories, which are the co-design process model and the identified game elements, assets, and challenges.

### 3.3 Participants

The research was conducted at the Toimentupa activity club (TAC) in Joensuu, Finland. The Finnish word "toimentupa" means a house or room of activity. The club meets voluntarily every working day with the purpose of prolonging and renewing the cognitive, social, and physical skills of older adults. Typical activities at TAC include handicrafts, social interaction, and discussions on various subjects. TAC members volunteered to be part of this research and met 13 times during the study period to co-design a multiple-choice word game from October 2016 until April 2019.

**Table 2** Progress of material analysis according to grounded theory (Corbin and Strauss 2015; Koskela 2011)

| | |
|---|---|
| 1. Open coding | Outcome |
| Knowledge of material | Substantial codes |
| Clearing the material | |
| Naming substantive codes | |
| Removing codes from text | |
| Starting a preliminary grouping | |
| 2. Axial coding | |
| Extending the categorization of substantive codes | Concepts |
| Creating subcategories and categories | |
| Characteristics of categories and subcategories | |
| 3. Selective coding | |
| Finding connections between concepts | Main categories (theory) |
| Finding a basic process | |
| Selecting core categories | |
| Formation of theory between concepts/relationships | |

Seven of the meetings were co-design workshops for creating a paper prototype and game content. After the first version of the game was programmed, the group met a further four times with the programmer (a Master's student) and the researcher (a Ph.D. student) to test the game and provide feedback. Meetings were typically held on a weekly basis, but this varied according to the participants' schedules. After the last meeting with the programmer, the participants were interviewed. At the beginning of the design process there were 8 members (2 males and 6 females age range 47–80 year (mean: 66.1 years old)), and at the end the group consisted of 3 members (1 male and 2 females age range 47–62 years (mean: 55.33 years old)).

The intergenerational perspective of game design was brought by the inclusion of 22 sixth graders (11 males and 11 females aged between 12 and 13) from the Hammaslahti primary school in Joensuu, Finland. The schoolchildren contributed modern words for the game; these words were commonly used among the children but were new to the older adults.

### 3.4 Ethical Approval

The parents of the pupils were asked to give permission for their children to participate in the study using a form sent home by the classroom teacher. One pupil's parents refused. The older adults participating in the study gave oral permission to participate in the study and to use their contributions in the study. The researcher agreed with the study participants that names and other identifiers would not be mentioned in any publication.

### 3.5 Procedure

Eight voluntary participants joined the process after the researcher distributed a general invitation among TAC members. Table 3 shows the schedule for the design meetings, their purpose, and attendance. The size of the group during the design sessions varied between three and seven. Towards the end of the design process, the group size stabilized at three. The group met 13 times in total to design the game.

**Table 3** Design meetings with older adults

| Meeting number | Purpose of the meeting | Participants | Time of the meeting |
|---|---|---|---|
| 1 | Introduction to the process and brainstorming for the game concept, interview 1 | 5 Females, 1 male | October 2016 |
| 2–8 | Creating content for the game | 3–5 Females, 1 male | November 2016–February 2017 |
| 9 | Interview 2 | 2 Females | March 2017 |
| 10–12 | Designing layout, playability, testing | 2 Females, 1 male | October 2017–April 2018 |
| 13 | Interview 3, evaluation, naming | 2 Females, 1 male | February 2019 |

The group focused on content design for seven of those meetings. The remaining meetings were dedicated to designing the game rules, the principles, and the layout and to evaluating and refining the game. Eventually, the team members evaluated the finished product. The programmer, who implemented a digital prototype of the game, participated in three of the meetings, once via Skype and twice in person.

The schoolchildren at the Hammaslahti primary school attended meetings three times in spring 2017 to co-design content for the game that was started by the older adults. The meeting schedule for the schoolchildren is presented in Table 4.

A team of two researchers collected observational and interview data for seven 1-h design sessions during which the older adult co-designers developed a game to learn new words and to maintain familiar but outdated words. The process took 1.5 years in total.

At the beginning, we organized a discussion and brainstorming session with the older adults about what kind of digital game could be interesting and meaningful for older adults. After the brainstorming, the PhD student interviewed (Interview 1) the older adults, asking questions such as "What kind of game do you want design?", "What are you expecting from the game?", and "What is the purpose of the game?"

The next seven meetings focused on creating content for the game. These were followed by an interview meeting (Interview 2) during which the PhD student asked the older adults the following questions: "What elements are important in a game?", "Have your expectations changed regarding the game?", and "What could be the competitive feature of the game?" The ideas that emerged from this interview were used in the subsequent design meetings.

The design meetings continued after the first two interviews, focusing on layout design, playability, and testing. During these meetings, a digital game prototype was programmed by the Master's student. After the design process was completed, the digital prototype of the game was evaluated by the older adults. During the last meeting, the Ph.D. student interviewed the older adults again (Interview 3), asking questions such as "What do you think about the game's playability?", "Does the finished game fulfil your ideas for the game?", and "Does the finished game fulfil your wishes for the purpose of the game?"

### 3.6 Data Collection and Analysis

The data pertaining to the older adult participants were collected using a video camera and an audio recorder during the design meetings and the interviews. Video recording allowed the participants full freedom to focus on their ideas and

**Table 4** Design meetings with Hammaslahti primary school pupils

| Meeting number | Purpose of the meeting | Participants | Time of the meeting |
|---|---|---|---|
| 1 | Creating content for the game | 11 Females, 11 males | January 2017 |
| 2 | Creating content for the game | 11 Females, 11 males | February 2017 |
| 3 | Creating content for the game | 11 Females, 11 males | March 2017 |

on designing. The video data was the main source data for the study because it is authentic and enables analyzing incidents as they actually happened (Derry et al. 2010). The interview meetings were used as the primary source for analysis. The other seven meetings were dedicated to creating vocabulary. All the interview data, along with the recordings of the co-design meetings, were transcribed and analyzed using GT (see Sect. 3.2).

The role of the schoolchildren in this study was to produce content (modern words and their meanings) for the game, which was passed to the researcher by email in the form of a text file. We collected video recordings from the co-design meetings with the schoolchildren, but these data are not used in this study.

## 4 Game Design Process

To facilitate the co-design process with older adults while also considering the intergenerational perspective, we developed a design process model that connects the roles of researchers as mediators, older adults and children as co-designers, and programmers as technology experts. Figure 1 shows the proposed design process model implemented in this study. The diagram is chronologically ordered from top to bottom and displays three actors:

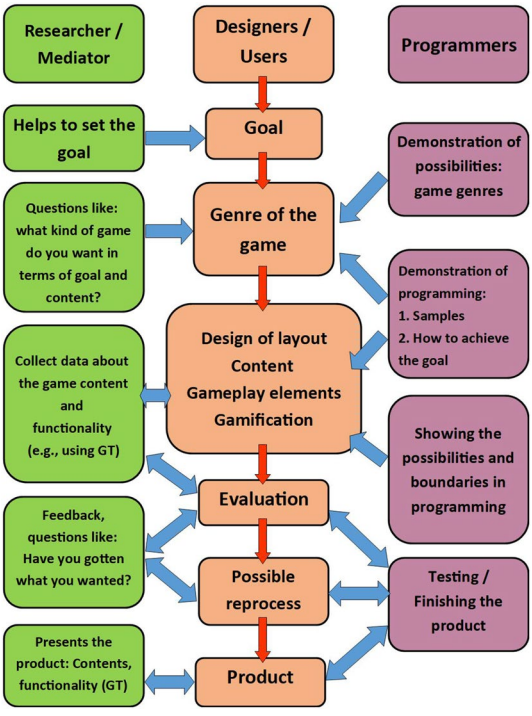


**Fig. 1** The co-design process model used in this study

1. The researcher/mediator (left),
2. The game co-designers (middle), and
3. The game programmers (right).

The design process progresses from setting a goal to the digital game as the final artefact. During the process, the game designers get a glimpse of the programming capabilities and constraints, but they initially design the game concept, layout, and content without any consideration of programming. The final game is a consensus of the designers' ideas and the constraints of programming; however, the final version of the game was approved by the designers.

The task of designing a digital game was introduced to the older adults at the first meeting, during which they set two goals for the game: it should help maintain memory and it should allow the player to learn something new.

A multiplayer game was chosen as a means of facilitating social interaction and potential intergenerational game playing. The game was designed to be played on a tablet computer because of their easy touch-based interface. The older adults started to design a multiplayer game to find explanations for words familiar from their childhood. These words which are often related to farming and the daily activities experienced in the lives of the older adults—during their childhood. Although words used in the lives of the older adults (during their childhood) are seldom spoken in contemporary Finnish society.

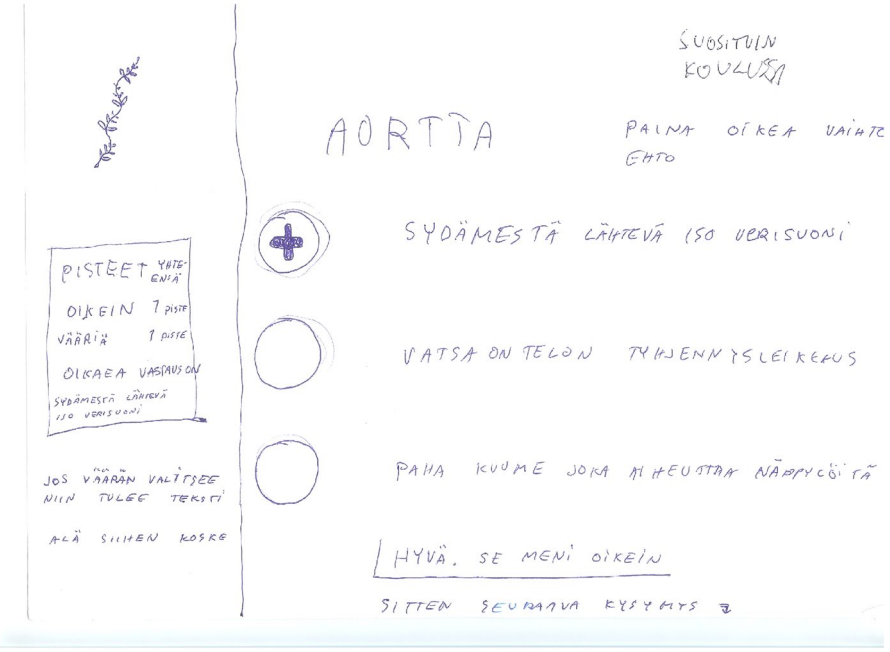


**Fig. 2** The layout plan of a designer (male, aged 47)

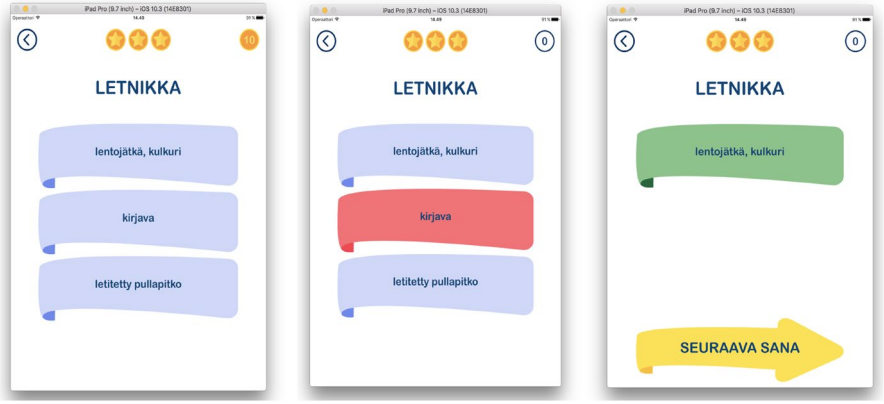


**Fig. 3** Example screenshots of a task in the *Onnen Tähti* game

**Table 5** English translations of some words in the *Onnen Tähti* game

| Word | English translation | Creators |
|---|---|---|
| Letnikka | A vagabond | Older adults |
| Atrain | A type of harpoon for fishing | Older adults |
| Tyven | Calm water surface of a lake | Older adults |
| Media | Media | Schoolchildren |
| Skypettää | To communicate via Skype | Schoolchildren |
| Tubettaa | To create videos for YouTube | Schoolchildren |

Figure 2 illustrates how the older adults created the layout and the gameplay concept of the game. In the design process, the members of the design team shared their perspectives on the Finnish language and made decisions related to the game co-design. The participants learned from and with each other about game design concepts and the Finnish language.

Following on from the second meeting onwards, the older adults chose words by brainstorming based on their experience and gave one correct and two incorrect definitions for each word. There are 75 words in total for which an explanation is requested. Figure 3 illustrates a task built within the final game. The picture on the left shows the starting position for the task with a word and three possible explanations. The middle picture shows a situation where the player has chosen an incorrect option (red). In the picture on the right, the correct answer is selected, and an arrow appears at the bottom of the screen saying, "Next word".

The role of the schoolchildren in this co-design process was to merely produce content, that issues contemporary/modern vocabulary. The schoolchildren created content by explaining the modern words that are likely to be new to older adults, for example words used in a digital context. Table 5 illustrates examples of the game's vocabulary created by the older adults and the schoolchildren.

Once the game content was created, the game was evaluated and improved upon by the older adult participants, the programmer, and the researcher. The game was

programmed for an iPad tablet device which was running the iOS operating system. The final artefact of the design process is the *Onnen Tähti* game. The name *Onnen Tähti* (English: Lucky Star) was suggested by one of the older adults at the evaluation phase during the last meeting held in February 2019.

In the co-design process, we considered the challenges related to games for older adults that were identified in previous research (see Sect. 2.3). These challenges and our solutions are presented in Table 6.

## 5 Results

### 5.1 Game Elements Identified as Important by the Older Adult Participants

After coding the data from the co-design meetings by GT with steps 1 (Open coding) and 2 (Axial coding), seven important game elements emerged from our analysis of the older adults' answers to question: "What elements are important in a game?" The elements are presented as results in Table 7 along with their descriptions and evidence from the collected data.

The results of our data analyses collected during the game design meetings and interviews were similar in content. We observed the following in relation to older adults, the game's content, action, and usability:

1. Experience of the gameplay situation in a *social sense*. In this case, one of the designers (female, aged 62) is a grandmother who wants to play the game with her grandchild. This designer's motivation to design is social.
2. Experience of a *similar gaming situation* where a previously played game resembles the to-be-designed game.

**Table 6** Challenges related to designing games for older adults and our proposed solutions

| Challenge | Solution in the game |
|---|---|
| Problem solving and reasoning | The game concept is simple and does not require complex problem solving, as players select the correct explanation for a word |
| Attention span and memory | The core idea of the game is to maintain memory |
| Visual processing | The game layout was designed to be clear and visually pleasing. The game functions are controlled by visual symbols |
| Auditory processing | There is no auditory feedback in the game |
| Unfamiliarity with technology | The interface is touch-based and does not require much experience with information technology |
| Unfamiliarity with gaming | The game is familiar to quiz-like games on printed material |
| Motor skills (e.g., reaction time, coordination, balance) | The player needs to find the correct option by touching a symbol. There is no time limit; therefore, fast reactions are not needed to play the game |
| Capturing and maintaining interest | The game content is about the game designers' own experience and the surrounding reality, which can help in capturing interest |

**Table 7** Important elements in games according to the older adult participants

| Elements | Description of elements | Evidence from the collected data |
|---|---|---|
| Appearance and aesthetics | The appearance and aesthetics of the game play an important role for older adults. It must be both pleasing and interesting and must conform to visual design guidelines for games for older adults (Ijsselsteijn et al. 2007; Weisman 1983) | "Now it looks good." (female, aged 62)<br>"If the game looks like this, it's boring." (female, aged 57) |
| Manageable gameplay | The easy and error-free gameplay and manageability of the game help older adults understand the gameplay and content of the game | "Collecting points: This is addictive!" (female, aged 62) |
| Social impact | The common experience of designing a game and playing together motivates older adults. Designing together with other older adults or other different groups produces meaningful content and engaging experiences for older adults | Members of the design team (female, aged 57; female, aged 62) mentioned the possibility of playing with a child, with an immigrant (with limited language skills), or anyone else |
| Familiarity | Previous positive game experiences may influence the designer in terms of wanting to have the same gameplay principles for the to-be-designed game. The principles of a previous, fun, and motivating gameplay experience can be, for example, based on board games or paper-based puzzles | "I would want to make it like the Sanapiilo game [a type of puzzle]." (female, aged 57) |
| Unpredictability | Randomness in game tasks increases interest in continuous gameplay. When words come in random order, the player's interest in the game is sustained for a longer time | "This is good when those (words) show up in a random order." (female, aged 62) |
| Competition | We found that competition is an important motivator to play for older adults, and it can be promoted by collecting points | "Now it is addictive" (female, aged 62) |
| Intergenerational gameplay | Intergenerational play motivates grandparents to play the game. The clarity of the game (layout, playability) allows older adults to play together with younger players | "I would like play this with my grandchild" (female, aged 62)<br>"Easy interface … possible to play for little children too." (female, aged 62) |

3. The *playability* and *aesthetics* of the layout were also highlighted in the interviews. One designer (female, aged 57) drew attention to the game's attractiveness at two meetings.

During this phase, the older adults identified four themes for further development in the evaluation meeting that supported the identified game elements in Table 7. These are: 1. social perspective: possibility to play alone or in a pair, 2. more interesting gameplay elements (e.g., competition), 3. more interesting appearance, and 4. the impact of the chance factor on gameplay.

Based on this feedback, the game was improved by including a point system. The last evaluation meeting was attended by two older adults (a male aged 47 and a female aged 57) almost 2.5 years after this project had commenced. The main reason for the last meeting was to demonstrate the finished artefact, to the older adults, to receive feedback from the older adults, and to discuss and choose a suitable name for the game. The feedback was aligned with the earlier evaluation.

### 5.2 Assets of Older Adults as Game Designers

Older adults as co-designers of a game can bring a myriad of various experiences, observations and perceptions to the different design meetings. Ageing can bring new perspectives to game design that younger designers may miss.

Based on the data analysis, we identified several assets that older adults have as game co-designers. These are presented in Table 8 along with our descriptions and evidence based on observations and interviews. While ageing obviously causes some obstacles for gaming (see Sect. 2.3), the identified assets that older adults have to offer for the design of digital games are versatile.

## 6 Discussion

### 6.1 From Game Players to Game Designers

Using digital technologies in contemporary society are part of daily activities and lives. Digital technology facilitates different aspects of life and can offer as a medium of entertainment. Older adults are active users of digital products and services (Dahlke et al. 2019) and therefore expect to find suitable applications and services on the market. Moreover, digital games have become an important part of everyday life for many young and older adults (Interactive Software Federation of Europe 2018), but most games are not designed for them, let alone with them.

The game industry should see older adults as an important consumer group; however, older adults continue to be excluded because they do not always have access to the digital world (Marston and Samuels 2019) and whilst there has been a growth in scholarly work focusing on the needs and design issues surrounding older adults and videogames (Flores et al. 2008; Gamberini et al. 2006; Gerling et al. 2012;

**Table 8** Assets of older adults as game designers

| Assets | Descriptions of assets | Evidence from the collected data |
|---|---|---|
| Ageing gives *time* | Ageing often means retirement and much free time for activities, such as designing games | Members of the design group had plenty of time over a long period of time for the design process and for meetings |
| Ageing enriches content for game design | A long life produces narratives, life stories, and experiences that can be used as resources in game concept and content design | Design group members had ideas for the game content anchored in their life experiences |
| Ageing can bring novel experience-driven ideas | Ageing can help in creating novel, out-of-the-box ideas for gameplay and content for the game | The members of the design group produced novel ideas and content based on their life experience |
| Older adults design for utility | Older adults expect the game to have meaningful content and gaming experience | The members of the design group wanted to create a game with useful content |
| Older adults are motivated to design games | Older adults are eager to co-design a game concept and content because they are motivated to share their own life experiences | The members of the design group were highly motivated based on their own life experiences. They were very enthusiastic to produce content using the vocabulary of their youth |
| Older adults dare to be honest | Older adults dare to comment on the game during its various design stages. They do not hesitate to be truthful | A comment in the middle of the design process criticizes a prototype of the game: "I wouldn't be interested in playing for a long time if this [game] is like this." (female, aged 57) |

Ijsselsteijn et al. 2007; Loos et al. 2019; Marston 2013a; Romero and Ouellet 2016; Vanden Abeele and Van Rompaey 2006; Veloso and Costa 2015; Weisman 1983), greater ressearch is needed. The next step is to understand and appreciate older adults' assets as designers of digital games of their own choosing.

The results of this study show that co-designing digital games with older adults is largely connected to their own life experiences and knowledge. They want to connect the game to their experiences, social life, and activities; and this notion supports existing work published by Marston (2013a, 2012). Older adults can offer valuable insights into the game design process because of their existing but varied knowledge and experiences. For example, in Table 7 we presented data, based on one of the older co-designers requesting to recreate a game that she had previously enjoyed playing.

This experience can be related to people's interactions, to familiarity with life-related phenomena, and to different special needs, like cognitive and physical limitations (Gerling et al. 2011). An example of designing based on a life-related phenomenon is Brukel, a first-person exploration game which was designed to show the perspective of a 92-year-old World War II survivor (Lifelong Games 2019). Designing a game is spontaneous and rich when the designer has a wide and diverse life experience, which in turn has been acquired over many years. Moreover, older adults have strong views about the game, which they are not afraid to share (see Table 8). Finally, as this study has shown, digital game design can be a tool for co-operation between different generations.

Our findings indicate that designing games is motivating from the point of view of older adults when the game has purposeful content and the gameplay situation itself is motivating. Moreover, playing the game is interesting when the game is consistent, when the content is understandable, when there is a clear purpose, and when it has an interesting. Yet, it is also important to note that the interface/game environment should be aesthetically pleasing, and this may require further testing, feedback and iterations of design and development by all of the team members.

### 6.2 Connection to Previous Work

As shown in Sect. 2.4, we found similar views relating to co-designing with older adults in existing research. Vanden Abeele and Van Rompaey (2006) highlight the central concept of a *meaningful game* as well as the importance of harnessing older adults' passions in the game co-design process. De Shutter and Vanden Abeele (2008) built upon this by proposing that a game's meaningfulness is related to fostering connections to family and friends, cultivating knowledge and skills, and contributing to society and to a better world. We saw a similar principle emerging in our analysis; meaningfulness in the game design generates motivation and facilitates content creation based on the life experiences of older adults. Romero and Ouellet (2016) noted the high motivation of their experimental group, which was also identified as a main driver in our study. The ability to reuse the experiences in one's own life was a motivating factor in game creation. Our experience is in line

with Loos et al.'s (2019) view on the importance of the social aspect between generations when designing and playing digital games. One of the older adults in this study indicated a desire to play with her grandchild. We also saw the ability of different age groups to produce interesting content together. Veloso and Costa (2015) emphasize co-design as a success factor in game design by older adults. Co-design can be used to create games suitable for the general public, which in the case of Veloso and Costa are primarily social network games. We had similar findings; the use of co-design helped the participants succeed in game design.

In order to produce games that are appropriate and interesting for an aging audience, Marston (2013a) suggests, among other recommendations, that the game and its content should: (i) offer simple and intuitive interaction, (ii) be related to real-world/life experiences, (iii) enable multiplayer/single play, (iv) build upon learning, (v) support user-created content, and (vi) have a purpose. These recommendations are aligned with our findings, as we presented older adults as game co-designers based on their life experiences and desire to learn new things. The main difference, however, is that this study introduces a new perspective to game co-design with older adults by granting game co-designers an opportunity not only to create game content but also to design an original game in terms of the concept, purpose, and mechanics. Additionally, the game's content and layout were produced as much as possible by the older adults whilst considering the ease of player–interface interaction, as suggested by Marston (2013a).

Our research in conjunction with existing scholarly work is driving forward the idea of co-designing games with older adults. The content of the *Onnen Tähti* game was produced by older adults and schoolchildren, thus demonstrating that intergenerational game design is possible. The older adult participants were instrumental in creating the game layout and game mechanics, and our findings suggest that they can be part of every aspect of the game design process. This expands the notion that older adults' participation in co-design is most appropriate in the ideation phase (Davidson and Jensen 2013). Finally, in our study only the programming was done by someone else, but perhaps in a future study we could explore the idea of older adults as co-designers and co-developers.

### 6.3 Challenges in Co-designing with Older Adults

This study taught us lessons on designing games with older adults, including several challenges that emerged in the design process. For example, one of the participants did not remember the researcher when they met outside of the research setting. Table 9 presents these challenges along with our proposed solutions. Challenges like these may not always be prevented, but with understanding and preparation all team members can be prepared. In particular, when co-designing with older adults, the practical arrangements (e.g. facilitating transportations, sending reminders) should be well planned to facilitate the commitment of the members of the design team in the co-design process. Acknowledging these challenges may help other researchers to avoid them or manage them to improve the overall co-design process. Overall, based

**Table 9** Challenges and proposed solutions related to co-designing with older adults

| Challenge | Description | Proposed solution |
|---|---|---|
| Availability of technical expertise | The limited time schedule of the programmer was a challenge in the design process. He did not have time to keep the original time schedule for the design meetings. Based on the design process model proposed in Fig. 2, the developer should be regularly available to listen to designers' feedback | Plan all participants' schedules in advance. Everyone involved in the project must be committed to the process as much as possible |
| Varying participation | There were a lot of changes in the group during the project. Part of the original group was left out of the design team soon after the beginning of the project | Regularly send reminders of meetings and telephone participants to keep them actively engaged in the design process. If necessary, provide transportation assistance |
| Health issues | One of the older adults did not recognize the researcher when they met outside the regular design meetings | Be aware of and consider the health status of each participant and prepare for absences from design meetings due to health issues |
| Logistics | Arrangement of transport due to reduced mobility. One member of the design team uses a walker | Organize transportation for group members who have mobility challenges |
| Diverse opinions | The older adults could not reach a consensus on all the game design options and layout features. Some of them wanted to keep their own ideas to the end, even though they could not include all their ideas in one game | Show suitable alternatives and facilitate negotiation to find a consensus. If there is time and resources, produce more game options |

on our co-design experiences with older adults, the assets they bring outweigh the challenges, many of which can be managed with appropriate precautions.

### 6.4 Answers to Research Questions

The findings of this study indicate that older adults consider specific game elements to be essential in designing good games, and their experiences comprise a useful resource for game co-design processes. However, we identified several challenges to be considered when co-designing digital games with older adults. In summary, the results of this study answer our research questions as follows:

1. What game elements are important for older adults as co-designers of digital games?
   We identified seven game elements that the older adult co-designers found particularly important to make games enjoyable. These are appearance and aesthetics, competition, manageable gameplay, social impact, familiarity, unpredictability, and intergenerational gameplay.
2. What are the assets of older adults in a digital game co-design process?
   Our analysis of the data revealed six assets that older adults may possess as game designers. Older adults' contribution to game creation can be enhanced by giving them the opportunity to use their own life experiences and demonstrate the potential of digital games to them in order to stimulate discussion. Their life experiences and networks can be a rich source of content for digital games, and we found that they are motivated to create game content based on their own life experiences.
3. What challenges might be encountered when co-designing digital games with older adults?
   We identified several challenges connected to co-designing with older adults: availability of technical expertise, varying participation due to different reasons, health and logistic issues caused by ageing, and diverse yet strong opinions.

### 6.5 Limitations of the Study

Several limitations were identified from this study and included, (i) The number of participants in the design group was small, and therefore the resulting game is based on the views and opinions of only a few designers. (ii) The proposed design process model was used to co-design only one game; therefore, its generalizability remains to be tested. (iii) The turnover of the participants in the design meetings was variable due to, among other things, the age of the participants. These limitations will be resolved in future studies where we will investigate how the proposed design process works with people of different backgrounds (e.g., age, education level, and culture).

## 7 Conclusion

The proportion of older adults worldwide is growing (United Nations 2017). Although digital games have become a popular pastime activity among older adults (Interactive Software Federation of Europe 2018), there is a limited number of studies on older adults and children as intergenerational digital game co-designers (de la Hera et al. 2017; Loos et al. 2019).

We contributed to this narrow but growing field by proposing a game co-design model and presenting a co-design process for a multiple-choice word game co-designed by a group of Finnish older adults and schoolchildren and by analyzing the data using GT. The analysis revealed the game elements that older adults consider important, their assets as game designers, and the challenges encountered in the process. While this study does not propose a completely new theory, it does offer novel insights on the co-design process with older adults and how it can lead to unexpected game designs.

The findings of this study suggest that older adults can facilitate the design of digital games using their assets acquired over a lifetime. Their life experiences allow for the creation of game content that is difficult or impossible for young people to create. The driving forces behind the successful co-design process of the *Onnen Tähti* game were the enthusiastic designers and their life experience. After we explained the digital, technical, and gaming aspects to the older adults, they eagerly accepted the opportunity and presented demanding layout ideas that challenged the capabilities of the programmer. Through the co-design process we understood that co-designing a digital technology can be a motivating experience that may also contribute to tackling of the challenge of digital exclusion (Marston and Samuels 2019).

This study introduced a new perspective to digital game design by giving older adult designers the ability to create not only game content but also the original starting point and gameplay of the game. The life experiences of older adults can help in creating unique content for games, and the co-design process can be rewarding for older adults and for those who work with them on digital technology. Although we had an intergenerational perspective in this study through the inclusion of schoolchildren as content designers, they did not contribute to other aspects of the game design, such as the game concept and layout. A natural part of this development is game co-design research where the purpose, concept, layout, content and other aspects of future game(s) can be decided upon or by mutual agreement with older adults and younger generations.

We encourage other researchers to take up the challenge of co-designing digital games with an intergenerational design team. In particular, there is a need for a future study that looks more closely at how diverse co-designers work together on a game design team and at what influence teamwork has on the co-design process and its results. Consequently, potential research questions to be explored include: (i) what are the differences and similarities in the assets between designers of different ages, genders, and cultural backgrounds? and (ii) how can designers of different ages, genders, and cultural backgrounds efficiently interact with each other in a game co-design process? Another interesting topic for future research is to explore

how design games (Vaajakallio and Mattelmäki 2014) could be used to add playfulness to digital game co-design processes, the effects they have on the design process and its outcomes, and whether they can help increase the commitment of the designers.

**Acknowledgements** Open access funding provided by University of Eastern Finland (UEF) including Kuopio University Hospital.



## References

Anderson, G. O. (2016). Video games: Attitudes and habits of adults age 50-plus. Washington, DC: AARP Research. https://doi.org/10.26419/res.00125.001

Bleakley, C. M., Charles, D., Porter-Armstrong, A., McNeill, M. D. J., McDonough, S. M., & McCormack, B. (2015). Gaming for health: A systematic review of the physical and cognitive effects of interactive computer games in older adults. *Journal of Applied Gerontology, 34,* NP166–NP189. https://doi.org/10.1177/0733464812470747.

Bloom, D. E., & Luca, D. L. (2016). The global demography of aging: facts, explanations, future. In *IZA discussion paper*.

Bonnechère, B., Jansen, B., Omelina, L., & Van Sint, J. (2016). The use of commercial video games in rehabilitation: A systematic review. *International Journal of Rehabilitation Research, 39,* 277–290. https://doi.org/10.1097/MRR.0000000000000190.

Boyle, E. A., Connolly, T. M., Hainey, T., & Boyle, J. M. (2012). Engagement in digital entertainment games: A systematic review. *Computers in Human Behavior, 28,* 771–780. https://doi.org/10.1016/j.chb.2011.11.020.

Brown, J. A. (2012). Let's play: Understanding the role and meaning of digital games in the lives of older adults. In *Proceedings of the international conference on the foundations of digital games*. ACM Press, Raleigh, North Carolina, p. 273. https://doi.org/10.1145/2282338.2282396

Chen, S., Huang, Y.-G. L., Chiang, I.-T. (2012). Using somatosensory video games to promote quality of life for the elderly with disabilities. In *International conference on digital game and intelligent toy enhanced learning*, pp. 258–262. https://doi.org/10.1109/DIGITEL.2012.68

Choi, S. D., Guo, L., Kang, D., & Xiong, S. (2017). Exergame technology and interactive interventions for elderly fall prevention: A systematic literature review. *Applied Ergonomics, 65,* 570–581. https://doi.org/10.1016/j.apergo.2016.10.013.

Corbin, J. M., & Strauss, A. L. (2015). *Basics of qualitative research: Techniques and procedures for developing grounded theory, Fourth* (edition ed.). Los Angeles: SAGE.

Cota, T. T., & Ishitani, L. (2015). Motivation and benefits of digital games for the elderly: A systematic literature review. *Revista Brasileira de Computação Aplicada, 7,* 2–16. https://doi.org/10.5335/rbca.2015.4190.

Dahlke, D., Lindeman, D., Ory, M. G. (2019). *No longer just for the young: 70% of seniors are now online*. World Economic Forum: Agenda. https://www.weforum.org/agenda/2019/07/no-longer-just-for-the-young-70-of-seniors-are-now-online. Accessed 16 Dec 19.

Davidson, J. L., & Jensen, C. (2013). Participatory design with older adults: An analysis of creativity in the design of mobile healthcare applications. In *Proceedings of the 9th ACM Conference*

*on Creativity and Cognition—C&C'13*. ACM Press, Sydney, Australia, p. 114. https://doi.org/10.1145/2466627.2466652

de la Hera, T., Loos, E., Simons, M., & Blom, J. (2017). Benefits and factors influencing the design of intergenerational digital games: A systematic literature review. *Societies, 7,* 18. https://doi.org/10.3390/soc7030018.

De Shutter, B., & Vanden Abeele, V. (2008). Meaningful play in elderly life. In *Proceedings of the annual meeting of the international communication association*, Montreal, Canada.

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., et al. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences, 19*, 3–53.

Flores, E., Tobon, G., Cavallaro, E., Cavallaro, F. I., Perry, J. C., Keller, T. (2008). Improving patient motivation in game development for motor deficit rehabilitation. In *Proceedings of the 2008 international conference in advances on computer entertainment technology*, ACM Press, pp. 381–384.

Gamberini, L., Alcaniz, M., Barresi, G., Fabregat, M., Ibanez, F., & Prontu, L. (2006). Cognition, technology and games for the elderly: An introduction to ELDERGAMES Project. *PsychNology Journal, 4,* 285–308.

Gerling, K. M., Schulte, F. P., Masuch, M. (2011). Designing and evaluating digital games for frail elderly persons. In *Proceedings of the 8th international conference on advances in computer entertainment technology—ACE'11. Presented at the the 8th international conference*, ACM Press, Lisbon, Portugal, p. 1. https://doi.org/10.1145/2071423.2071501

Gerling, K. M., Schulte, F. P., Smeddinck, J., Masuch, M. (2012). Game design for older adults: Effects of age-related changes on structural elements of digital games. In *11th International conference on entertainment computing*, pp. 235–242. https://doi.org/10.1007/978-3-642-33542-6_20

Glisky, E. L. (2007). Changes in cognitive function in human aging. In *Brain aging: Models, methods, and mechanisms*. CRC Press/Taylor & Francis.

Griffiths, M. D., Kuss, D. J., & Ortiz de Gortari, A. B. (2017). Videogames as therapy: An updated selective review of the medical and psychological literature. *International Journal of Privacy and Health Information Management, 5,* 71–96. https://doi.org/10.4018/IJPHIM.2017070105.

Hall, A. K., Chavarria, E., Maneeratana, V., Chaney, B. H., & Bernhardt, J. M. (2012). Health benefits of digital videogames for older adults: A systematic review of the literature. *Games for Health Journal, 1,* 402–410. https://doi.org/10.1089/g4h.2012.0046.

He, W., Goodkind, D., Kowal, P. (2016). *An aging world: 2015 (No. P95/16-1)*, International Population Reports. United States Census Bureau.

How, T.-V., Hwang, A. S., Green, R. E. A., & Mihailidis, A. (2017). Envisioning future cognitive telerehabilitation technologies: A co-design process with clinicians. *Disability and Rehabilitation: Assistive Technology, 12,* 244–261. https://doi.org/10.3109/17483107.2015.1129457.

Ijsselsteijn, W., Nap, H. H., de Kort, Y., Poels, K. (2007). Digital game design for elderly users. In *Proceedings of the 2007 conference on future play*. ACM Press, pp. 17–22.

Interactive Software Federation of Europe. (2018). *GameTrack digest: Quarter 4 2017*. Brussels, Belgium.

Kankainen, A., & Lehtinen, V. (2011). Creative personal projects of the elderly as active engagements with interactive media technology. In *Proceedings of the 8th ACM conference on creativity and cognition—C&C'11*. ACM Press, Atlanta, Georgia, USA, p. 175. https://doi.org/10.1145/2069618.2069648

Koskela, H. (2011). Lapseni elää aina sydämessäni: lapsen menetyksen merkitys vanhemman spiritualiteetin muotoutumisessa, Kirkon tutk. kesk. julkaisuja. Kirkon tutkimuskeskus.

Larsen, L. H., Schou, L., Lund, H. H., & Langberg, H. (2013). The physical effect of exergames in healthy elderly: A systematic review. *Games for Health Journal, 2,* 205–212. https://doi.org/10.1089/g4h.2013.0036.

Lehto, P., & Rantanen, T. (2017). Robotics in homecare: The development process through a case study. In *Proceedings of the international technology, education and development conference*. Valencia, Spain, pp. 3444–3452. https://doi.org/10.21125/inted.2017.0864

Lifelong Games. (2019). Brukel.

Lim, J., Zhan, A., Ko, J., Terzis, A., Szanton, S., & Gitlin, L. (2012). A closed-loop approach for improving the wellness of low-income elders at home using game consoles. *IEEE Communications Magazine, 50,* 44–51. https://doi.org/10.1109/MCOM.2012.6122531.

Loos, E., de la Hera, T., Simons, M., Gevers, D. (2019). Setting up and conducting the co-design of an intergenerational digital game: A state-of-the-art literature review. In *International conference on human–computer interaction*. Orlando, Florida, pp. 56–69.
Marston, H. (2010). Wii like to play too: Computer gaming habits of older adults (Doctoral dissertation). Teesside University, Middlesbrough, UK.
Marston, H. (2012). Older adults as 21st century game designers. *The Computer Games Journal, 1,* 90–102. https://doi.org/10.1007/BF03392330.
Marston, H. (2013a). Design recommendations for digital game design within an ageing society. *Educational Gerontology, 39,* 103–118. https://doi.org/10.1080/03601277.2012.689936.
Marston, H. (2013b). Digital gaming perspectives of older adults: Content vs. interaction. *Educational Gerontology, 39,* 194–208. https://doi.org/10.1080/03601277.2012.700817.
Marston, Hannah, Freeman, S., Bishop, K. A., & Beech, C. L. (2016a). A scoping review of digital gaming research involving older adults aged 85 and older. *Games for Health Journal, 5,* 157–174. https://doi.org/10.1089/g4h.2015.0087.
Marston, H., & Hall, A. K. (2016). Gamification: Applications for health promotion and health information technology engagement. In *Handbook of research on holistic perspectives in gamification for clinical practice*. IGI Global, Hershey, PA, USA, pp. 78–104.
Marston, Hannah, Kroll, M., Fink, D., & Gschwind, Y. J. (2016b). Flow experience of older adults using the istoppfalls exergame. *Games and Culture, 11,* 201–222. https://doi.org/10.1177/1555412015605219.
Marston, H., & Samuels, J. (2019). A review of age friendly virtual assistive technologies and their effect on daily living for carers and dependent adults. *Healthcare, 7,* 49. https://doi.org/10.3390/healthcare7010049.
Marston, H., & Smith, S. T. (2012). Interactive videogame technologies to support independence in the elderly: A narrative review. *Games for Health Journal, 1,* 139–152. https://doi.org/10.1089/g4h.2011.0008.
Marston, H., Woodbury, A., Gschwind, Y. J., Kroll, M., Fink, D., Eichberg, S., et al. (2015). The design of a purpose-built exergame for fall prediction and prevention for older people. *European Review of Aging and Physical Activity, 12,* 13. https://doi.org/10.1186/s11556-015-0157-4.
McGee-Lennon, M., Smeaton, A., Brewster, S. (2012). Designing home care reminder systems: lessons learned through co-design with older users. In *Proceedings of the 6th international conference on pervasive computing technologies for healthcare*. IEEE, San Diego, USA. https://doi.org/10.4108/icst.pervasivehealth.2012.248684
McLaughlin, A., Gandy, M., Allaire, J., & Whitlock, L. (2012). Putting fun into video games for older adults. *Ergonomics in Design: The Quarterly of Human Factors Applications, 20,* 13–22.
Merkel, S., & Kucharski, A. (2019). Participatory design in gerontechnology: A systematic literature review. *The Gerontologist, 59,* e16–e25. https://doi.org/10.1093/geront/gny034.
Miller, K. J., Adair, B. S., Pearce, A. J., Said, C. M., Ozanne, E., & Morris, M. M. (2014). Effectiveness and feasibility of virtual reality and gaming system use at home by older adults for enabling physical activity to improve health-related domains: A systematic review. *Age and Ageing, 43,* 188–195. https://doi.org/10.1093/ageing/aft194.
Romero, M., & Ouellet, H. (2016). Scaffolding digital game design activities grouping older adults, younger adults and teens. In J. Zhou & G. Salvendy (Eds.), *Human aspects of IT for the aged population: Design for aging* (pp. 74–81). Cham: Springer. https://doi.org/10.1007/978-3-319-39943-0_8.
Salen, K., & Zimmerman, E. (2003). *Rules of play: Game design fundamentals*. Cambridge: The MIT Press.
Schell, J. (2014). The art of game design: A book of lenses, second edition. A K Peters/CRC Press. https://doi.org/10.1201/b17723
Scialfa, C. T., & Fernie, G. R. (2006). Adaptive technology. In *Handbook of the psychology of aging*. Academic Press, London, pp. 425–441.
Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., et al. (2016). Do "brain-training" programs work? *Psychological Science in the Public Interest, 17,* 103–186. https://doi.org/10.1177/1529100616661983.
Steen, M., Manschot, M., & De Koning, N. (2011). Benefits of co-design in service design projects. *International Journal of Design, 5,* 53–60.
Stine-Morrow, E. A. L., & Basak, C. (2011). Cognitive interventions. In *Handbook of the psychology of aging*. Elsevier, pp. 153–171. https://doi.org/10.1016/B978-0-12-380882-0.00010-3.
Treadaway, C., & Kenning, G. (2016). Sensor e-textiles: person centered co-design for people with late stage dementia. *Working with Older People, 20,* 76–85. https://doi.org/10.1108/WWOP-09-2015-0022.

United Nations. (2017). *World population ageing 2017: Highlights (No. ST/ESA/SER.A/397)*. United Nations, Department of Economic and Social Affairs, Population Division, New York, NY.

Vaajakallio, K., & Mattelmäki, T. (2014). Design games in codesign: As a tool, a mindset and a structure. *CoDesign, 10,* 63–77. https://doi.org/10.1080/15710882.2014.881886.

Vanden Abeele, V. A., & Van Rompaey, V., (2006). Introducing human-centered research to game design: Designing game concepts for and with senior citizens. In *CHI'06 extended abstracts on human factors in computing systems—CHI EA'06*. ACM Press, Montreal, Canada, p. 1469. https://doi.org/10.1145/1125451.1125721.

Veloso, A., & Costa, L. (2015). Social network games in an ageing society: Co-designing online games with adults aged 50 and over. In *2015 10th Iberian conference on information systems and technologies (CISTI)*. IEEE, Aveiro, Portugal, pp. 1–6. https://doi.org/10.1109/CISTI.2015.7170613.

Weisman, S. (1983). Computer games for the frail elderly. *The Gerontologist, 23,* 361–363.

Wiemeyer, J., & Kliem, A. (2012). Serious games in prevention and rehabilitation: A new panacea for elderly people? *European Review of Aging and Physical Activity, 9,* 41–50.

Wintermans, M. C., Brankaert, R. G. A., Lu, Y. (2017). Together we do not forget: co-designing with people living with dementia towards a design for social inclusion. In *Proceedings of the design management academy conference 2017*. Hong Kong.

Woods, R. T. (2004). Problems in the elderly: Investigation. *The Handbook of Clinical Adult Psychology* (pp. 413–437). London: Routledge.

World Health Organization. (2002). *Proposed working definition of an older person in Africa for the MDS Project. Health statistics and information systems*. https://www.who.int/healthinfo/survey/ageingdefnolder/en/. Accessed 16 Dec 2019.

Yamamoto, G., Hyry, J., Krichenbauer, M., Taketomi, T., Sandor, C., Kato, H., Pulli, P., (2015). A user interface design for the elderly using a projection tabletop system. In *Proceedings of the 3rd IEEE VR international workshop on virtual and augmented assistive technology*. Arles, France.

Zhang, F., & Kaufman, D. (2015). Physical and cognitive impacts of digital games on older adults: A meta-analytic review. *Journal of Applied Gerontology*, pp. 1–22.