The impact of exergames: A panacea for older adults' wellbeing?

Using narrative literature reviews to make sense of exergaming in later life

Eugène Loos

ACT grant 895-2013-1018

Two older adults playing an exergame (Zonneveld, 2013)

Foreword

We would like to thank ACT for financially supporting this research project (grant 895-2013-1018), the chair "Old and New Media in an Ageing Society" at the University of Amsterdam for the research time and Utrecht University Master's student Nynke Meijer for her help with the narrative literature reviews.

Eugène Loos

Utrecht, December, 2 2016

Contents

1. Introduction

You may wonder what you see here:

Figure 1.1: Screenshot (Zonneveld, 2013)

To the left is a *virtual* Tai Chi instructor, while on the right is a representation of an older adult on a computer screen trying to follow the instructions given by the instructor; the number of calories burned (3) are shown in the lower right-hand corner. The miniature table flag next to the screen is from the Dutch senior citizens organisation, ANBO, the host of this research project. The project itself is aimed at understanding how older adults make sense of exergames.

The picture below shows you *the real life* setting:

Figure 1.2: Older adult playing a Tai Chi exergame (Zonneveld, 2013)

The older adult in Figure 1.1 and 1.2 is playing an exergame. Exergames, which are also known as "active video game, interactive video game, activity promoting video game" (Oh & Jang, 2010, p.10), consist of an electronic device that allows one or more persons to play a game "requiring physical exertion or movements" (Oh & Jang, 2010, p.10), while receiving immediate digital performance feedback on a screen (see also Primack et al., 2012, p. 3). Kooiman & Sheehan (2015) state that:

> Until recently exergaming was seldom a topic of research. The technology that makes exergaming possible was not available to consumers. In 2006, Nintendo released the Wii gaming system. This new system allowed for interactive physical movement beyond simple hand held play. The Wii system contained hardware and software that responded to movements of the player's body through the tracking of hand held controllers and movements of the lower extremities using floor based hardware. (p. 1)

The Dutch historian Johan Huizinga **(**1950 [1938]**)** viewed games as a fundamental aspect of life. As long ago as 1938, he observed that, next to "homo faber" (man the maker), there is also the concept of "homo ludens" (man the player). Since then, as Bogost (2007) pointed out, we have become as used to playing digital games in the living room as watching television (see also Juul (2012) on "casual gaming). Several studies have suggested that playing exergames can, to some extent (the evidence tends to be limited), benefit the wellbeing of *children and young adults* (see Table I.1), and hence could form a potential valuable therapeutic instrument (e.g., Daley, 2009; Papastergiou, 2009; Biddiss & Irwin, 2010; Peng et al., 2012; Baranowski et al., 2016). Other studies have demonstrated that *older adults* are interested in traditional games (e.g., Hoppes et al. 2000, 2001), leading Hoppes et al. (2000) to conclude that "Games are a purposeful activity that hold high interest for older adults and consequently have significant value as therapeutic tools for occupational therapists." (p. 71)

Table I.1. Impact of exergames on younger people: literature reviews and white paper

	Number of studies	Target group	Medium	Impact on …	Evidence based?
1. Daley (2009)	Systematic Literature Review 14 descriptive studies 1 uncontrolled trial study 2 pilot randomized, controlled trials (RCTs)	Children	Exergames	Physical activity (energy expenditure): "There is some evidence that exergaming uses significantly more energy than sedentary activities (…)" (p. 769)	"(…) evidence to date is mixed on whether they engage children in levels of activity that are consistent with public health recommendations for physical activity and improving cardiorespiratory fitness." (p. 769
2. Papastergiou (2009)	Literature Review 34 studies	Young people	Computer and video games	Health Education (HE) and Physical Education (PE). Potential benefits as educational tools for HE and PE. Improvement of knowledge, skills, attitudes and behaviours in relation to health and physical exercise. Physically interactive games: enhancement of physical fitness, motor skills, motivation for physical exercise.	"The empirical evidence to support the educational effectiveness of electronic games in HE and PE is still rather limited, but the findings present a positive picture overall." (p. 603)
3. Biddiss & Irwin (2010)	Systematic Literature Review 18 studies	Children and youth	Active Video Games (AVG)	Energy expenditure during AVG play compared with rest (12 studies) and activity with AVG exposures (6 studies): "The AGGs enable light to moderate physical activity." (p. 664)	"Limited evidence is available to draw conclusions on the long-term efficacy of AVGs for physical activity promotion." (p. 664)

4. Barnett et al. (2011)	Systematic Literature Review 9 studies	Children, Youth Adolescents	Active Video Games	Energy expenditure and maintenance of play: "AVGs are capable of generating EE in youth to attain PA guidelines. Few studies have assessed sustainability of AVG play, which appears to diminish after a short period of time for most players." (p.724)	"The meta-analytic estimates of average METs across these studies were 3.1 (95% CI: 2..6, 3..6) to 3..2 (95% CI: 2. 7, 3..7)." (p. 724)
5. Guy et al. (2011)	Systematic Literature Review 34 studies	Children	Active and Educational Video Games	Diet and physical activity in children. "Results of these studies that showed some benefit (increased physical activity and nutritional knowledge as a result of gaming) demonstrate the possibility of video games to combat childhood obesity—looking beyond the stigma attached to gaming."	"Research has proven that AVG use can elicit light to moderate physical activity among youth. While we are not advocating that a child only plays video games to get their recommended daily physical activity, we are proposing that physical activity as a result of AVG engagement can contribute toward daily recommendations of physical activity."
6. Peng et al. (2012)	Systematic Literature Review 13 interventions 28 laboratory studies	Children and adults	Active Video Games	"All laboratory studies demonstrated that AVGs are capable of providing light-to-moderate intensity physical activity. However, only three interventions supported AVGs as an effective tool to significantly increase physical activity or exercise attendance." (p.1)	Laboratory studies: yes. Interventions: only 3 out of 13.

7. LeBlanc et al. (2013)	Systematic Literature Review 51 studies	Children and youth	Active Video Games (AVG)	Physical activity "While controlled laboratory studies clearly demonstrate that a motivated player can obtain some light- to moderate-intensity PA from most AVGs." (p. 18)	(…) the findings are inconsistent about whether, or the circumstances under which, having an AVG results in sustained PA behaviour change, or for how long the behaviour change persists. Some of these games offer nuances on game play that could be related to increased PA or decreased sedentary behaviour." (p. 18)
8. Lu et al. (2013)	Systematic Literature Review 14 studies	Children	Health Videogames	"Results indicated that academic interest in using health videogames for childhood obesity prevention has increased during this time. Most games were commercially available. Most studies were of short duration." (p. 131)	"Most of the games were commercially available. Positive outcomes related to obesity were observed in about 40 percent of the studies, all of which targeted overweight or obese participants." (p. 131)
9. Baranowski et al. (2016)	White Paper 161 studies	Children and adolescents	Games for Health	"Although early outcome results are promising, additional research is needed to determine the game design and behavior change procedures that best promote G4H effectiveness and to identify and minimize possible adverse effects." (p. 1)	n/a

The purpose of this study is to explore the role exergames could play in promoting the wellbeing of older adults. In doing so, we were guided by the following questions:

1. Are older adults *willing to* play exergames?
2. Are older adults *able to* play exergames?
3. What is the *impact* of playing exergames on older adults' *wellbeing*?

To answer these questions, narrative literature reviews were used to gain insight into the factors relating to older adults' engaging (or not) in exergames and the impact which playing these games has on their wellbeing, but also into the ways *older adults themselves experience* playing exergames. By avoiding a functionalist perspective on play, we are also able to include hedonic aspects of playing digital games (Lieberman, 2006; McLaughlin et al., 2012; De Schutter & Brown, 2016; Gerling et al., 2015). As Iversen (2014) states in her paper 'Play and Productivity: The Constitution of Ageing Adults in Research on Digital Games' in which she reviews studies on the impact of digital games for older adults' daily life:

> While there are exceptions, the ageing adults in the examined studies are largely portrayed as ailing, hesitant, in need of encouragement to do what is good for them as well as requiring the care of others. This outlook is coupled with a mainly functionalistic approach to the use of digital games, where the beneficiality of playing in terms of health maintenance is central rather than, for instance, enjoyment, pleasure, or creativity. Importantly, it is not only the researchers who invoke the beneficiality of digital games above other reasons for playing. To the degree that the ageing adults themselves are given voice, they often, too, focus on learning and training elements of digital games. (p. 14)

The aim of this research report is to explore what we can learn from previously conducted empirical studies about the motivation and capability of older adults to use exergames as a therapeutic instrument and the impact on their wellbeing. As Kari et al. (2012) state:

> Physical activity has been shown to have a positive impact on people's well-being. According to WHO (2012a), regular physical activity can, among others, reduce the risk of diabetes, cardiovascular diseases, depression, breast cancer, and colon [cancer]. It can also improve bone and functional health (WHO, 2012b) and have other important health benefits. (p. 30)

Although attention is also given to the empirical evidence on the impact of playing such games, the focus is on exploring how older adults make sense or do not make sense of such games. So, no systematic literature reviews were performed and sections 2.2, 2.3 and 2.4 therefore present the results of the narrative literature reviews we conducted (Lewis-Beck et al., 2003). As mentioned earlier, these results are not only used to present facts and figures, but also to give voice to the ways older adults themselves experience playing exergames. Finally, we note that the studies included in the narrative literature reviews are focused on older adults.

2. Exergaming in later life: Literature reviews

2.1 Introduction

According to the Entertainment Software Association ESA (2016), the number of US older adults playing digital games, sometimes called 'baby boomer gamers' (Pearce, 2008) is considerable: in 2016, 26% of all gamers are aged 50 or older. A similar picture emerges in the countries of Europe. According to Iversen (2004), who refers to Bak et al. (2012), Nordicom-Sverige, 2012, p. 2) and Vaage (2012), "national surveys on the use of media in Norway, Sweden, and Denmark indicate that - varying between the countries- 5–12% of the population above 60 years of age play digital games at least once a day" (p. 2). Loos et al. (submitted b) confirm this trend for the Netherlands: "New Zoo (the only source for reliable data on Dutch older adults' use of digital games) clearly shows that (…) in 2013 39% of the 51-65 year-olds play digital games." We agree with Pearce (2008), who emphasizes that baby boomer gamers have "needs and interests that have gone ignored by both the mainstream game industry and the game press" (p. 142). In reviewing the literature in this area, we will examine whether the voices of the baby boomer players can be heard in the empirical studies on exergaming in later life.

2.2 Are older adults *willing to* play exergames?

Sherry et al. (2006) conducted focus groups with four to eight participants (age 18 to 22, U.S. American undergraduate students, N = 96), adopting a Uses and Gratifications perspective (Ruggiero, 2000). They concluded that the dimensions arousal, challenge, competition, diversion, fantasy and social interaction were the motivations for the participants to play video games. In this section, we use their classification to gain insight into the motivations of *older adults* for playing – or not playing - *exer*games. We used the framework developed by Sherry et al. (2006), adding column for dimensions (e.g. exercising) no included in their framework. The results are presented in Table 2.1 A dimension marked with a + means that the exergames were experienced as enabling wellbeing; a – denotes that this dimension was experienced as a barrier to playing.

Table 2.1. Why older adults (do not) play exergames

	Dimensions:	Arousal	Challenge	Competition	Diversion	Fantasy	Social Inter-action	Other Dimensions
1. Graves et al. (2010)					+			
2. Aarhus et al. (2011)				+	+		+	+ Exercises framed as play + Physical wellbeing + Feedback - Speed - Usability (complexity of what is displayed) - Native language not available - Display of personal data (BMI and Wii age)
3. Brox et al. (2011)								+ Active and friendly user interface
4. Kari et al. (2012)					+			+ Exercise Top 5 - - No interest - Prefers other forms of exercise - Ownership - Money - Not useful enough

5. Omholt & Waer-stad (2013)		+		+	+		+	+ **Clear instructions** + **Clear goals** + **Possibility to achieve goals** + **Mastery (simple and easily comprehended interface)** + **Feedback** + **Opportunity to experience real life situations** + **Motivating story** + **Accessibility and low price**

6. Heuve-link (2014a)		+	+	+	+	+	+	+ **Exercise** + **Mastery (capability to do the activity)** + **Safety (no risk to fall)** + **Easy to play** + **Feedback** + **Reward (intrinsic)** + + **Larger variety of activities** + **Opportunity to experience the dynamics of real life situations** + **Discover new things** + **Fit with older adults' interests** + **Not being dependent on others** + **Challenging *oneself***

7. Heuvelink (2014b)			+		+		+	+ Physical activity / wellbeing + To get out of the house + To try something new + To be mentally active Top 3 - - Lack of interest - No added value - Not wanting to spending money on a system
8. Skalsky Brown (2014)				+	+	+	+	+ Continuance of a traditional form of play + Something to do + Cognitive maintenance
9. Cota & Ishitani (2015)							+	+ Use of narratives + Low level of difficulty and complexity of the game + Association with traditional games + Preference for casual games

10. Loos & Zonne-veld (2016)			+		+		+	+ **Autonomy and competence (Social Determination Theory)** + **Exercise (physical and social wellbeing)** + **New ways to exercise** + **Alternative to current exercise programs** + **Possibility to practice sports played in the past** + **Mastery (easy to learn to play)** - **No added value** - **Native language not available** - **Not adapted to the national culture (surroundings)** - **Not as attractive as outdoor exercise activities more** - **Unfamiliar surroundings or movements**

The Table above shows that older adults rarely mentioned the motive dimensions in the framework developed by Sherry et al. (2006) of arousal, competition and fantasy; challenge is somewhere in the middle, while diversion and social interaction are mentioned most often. In the 'other dimension' column, Exercising, Feedback and Mastery of the design were mentioned often. Poor usability was mentioned as the dimension most experienced as a barrier to playing.

Lastly, we found that only four of the ten studies reviewed gave a voice to older adults, allowing them to explain why they do or do not play exergames. Let us listen to some of these older adults' voices:

Aarhus et al. (2011): *It isn't fun to do it alone. I'd rather have someone to talk to while doing it.* (p. 113)

Omholt & Waerstad (2013) : *If there is going to be any point in doing something together, it needs to be that you are enhancing each other. Like that you get a better result if you are cooperating.* (p. 130)

Skalsky Brown (2014): *I enjoy it [digital games] and it's fun and it's okay to have fun… It's okay for me to relax and have fun and enjoy myself, but that's been a hard thing for me to let go of… that I can cut back on my work. I can slow down some and pick and choose and do what I want to do. So that has been the hard part for me, at this age.* (p. 90)

Loos & Zonneveld (2016): *I experienced no pressure while playing, at the most a challenge because it's fun to play and because you're striving to achieve something and you see the scores rising, so that provides the challenge.* (p. 335)

2.3 Are older adults *able to* play exergames?

In section 2.1 we saw that older adults in countries such as the USA, Norway, Sweden, Denmark and the Netherlands play digital games. Nevertheless, there are numerous older adults who

refrain from doing so. Kari et al. (2012), in a study among Finnish (non)players of exergames in different age groups, found that:

> In the two oldest age groups of 35– 44 years and 45 years or over, the three most significant reasons [for not playing an exergames] were 1) no interest, 2) prefers other forms of exercise, and 3) ownership (…). In the youngest age group, the reason no money was the most significant one. The most significant differences between age groups were in the reasons no money and no interest. No money was more significant the younger the age group was. (p. 11)

In a study among US older adults who did not play digital games, Skalsky Brown (forthcoming) found that lack of motivation was by far the most important factor:

> Older adults who engage in digital games typically have at least a moderate degree of three domains that interplay with one another: motivation, experience with game-related technology, and functional ability (Skalsky Brown, 2014). To assess these domains among non-gamers, I interviewed persons over the age of 60 to explore whether or not any of these aspects surfaced as being deficient. Although most touched upon some concerns pertaining to their functional ability (declining) and limited tech experience, this paled in comparison to their level of motivation to play. Motivations varied widely among the older gamers, yet the strength of the individual motivation was strong enough to negate the other two domains if they were somewhat lacking. With the older non-gamers I interviewed, all but one stated that they simply had no interest in playing, as they believe they had better things to do with their time. Even when I posed the potential of playing as a means of intergenerational play (e.g., playing with grandchildren), this typically wasn't enough of a motivator, which surprised me. (personal communication, 10.10.2016)

Another point to take into consideration is the so-called "I"-methodology. Williams et al. (2009) state that the majority of digital games designers (88,5%) are young (average age 31) male adults with highly developed ICT skills. Loos (2014) and Loos et al. (submitted a) argue that as typical young male adults, these game designers might have little understanding of the needs of older adults, causing them to fall into the I-methodology trap:

> The I-methodology refers to a design practice in which designers consider themselves as representative of the users (Akrich, 1995). Akrich describes the I-methodology as the "reliance on personal experience, whereby the designer replaces his professional that by that of the layman" (Akrich, 1995, p. x). This is often an unconscious process: the designer is not aware of the fact that the user representation he or she is using resembles himself or herself. In contrast to the images created by designers and what people expect, implicit methods are often more powerful than explicit methods in shaping the design. (Oudshoorn et al., 2004, p. 41)

Loos (2014) and Loos & Romano Bergstrom (2014) argue that young male game designers may specifically tend to overlook the aspect of age-related functional limitations due to the factors mentioned in the Table below.

Table 2.2. Studies on age-related functional limitations due to …

Declining vision: difficulties in seeing and processing cluttered online content and difficulties reading the screen	Charness, 2001; IJsselsteijn et al., 2007; Lunn & Harper, 2009; Billis et al., 2010; Vasconcelos et al., 2012; Omholt & Waerstad, 2013; Skalsky Brown, 2014
Useful field of view: difficulties in detecting items in the periphery of screens	Bergstrom et al., 2016
Decreased attention division skills: difficulties in processing multiple forms of information (e.g., text and speech) simultaneously	Czaja & Lee, 2007; IJsselsteijn et al., 2007; De Bruin et al., 2010; Aarhus et al, 2011

Hearing: difficulties in detecting high-frequency alerting sounds (beeps or pings)	IJsselsteijn et al., 2007; Czaja & Lee, 2009; Billis et al., 2010; Omholt & Waerstad, 2013
Visual motor-coordination: difficulties in using a computer mouse track	Schueren, 1986; Smith et al., 1999; Theng (2009); Diaz-Orueta et al., 2012; Vasconcelos, et al., 2012; Skalsky Brown, 2014
Physical constitution: health issues such as arthritis, bad backs, reduced balance	Pearce, 2008; Olmholt & Waerstad, 2013
Cognition: older adults are much slower than youngers adults	Salthouse, 1996, 2004; Vercruyssen, 1997; Brown & Park, 2003; IJsselsteijn et al., 2007; Czaja & Lee, 2007; Billis et al., 2010; Aarhus et al., 2011; Vasconcelos et al., 2012; Olmholt & Waerstad, 2013; Skalsky Brown, 2014

We agree with De Schutter et al. (2015) that "Designers must be aware of normative age-related changes and (1) how such aspects can affect technological interaction (e.g. reduced vision and hearing, slower pace, decreased attention division skills, etc., IJsselsteijn et al., 2007)." (p. 1171)

Of the studies presented in the Table above, quotes from older adults were only found in Skalsky Brown (2014):

> *I definitely use reading glasses when I game. I find I like to sort of recline when I game in my chair, sort of lean back like this and game. And I find I frequently have to sit up because I can't read the screen, so I have a lot more problems in some kinds of games. Some games are not very good at adjusting font sizes. So if you, say, run the game at high resolutions, the graphics look good. The graphics all scale so things are still the same size or just higher resolution, but all the text gets really small. And that can be very frustrating because I can't read it unless I lean up to the machine. So there are games out there where I actually can find it very hard sometimes to identify what's going on the screen because of the complexity that can now be shown with high-end... you know, high ... modern processors and graphics quality.* (p. 104)

As age-related functional limitations occur with a certain regularity from age 75 on, and are common from age 85 and up (Bouma, 2000), these must be taken into account by designers of

exergames, to avoid having older adults who are willing to play exergames (see section 2.2) being hindered by factors due to biological ageing. De la Hera et al. (submitted) give a specific example of how it would be possible to counter the problem of decreased speed by suggesting that "in-game adjustable speeds might be an option to support older players for whom time-restricted games are a challenge (Nap et al., 2009)."

2.4 What is the impact of playing exergames on older adults' wellbeing?

In this section, we present the effects of exergames specifically on the wellbeing of older adults. The results of studies such as those of Aarts & Nøhr (2010) and Primack (2012), which are focused on all generations, have therefore been left out of consideration. Nor do we focus on the design of such games (see for more information IJsselsteijn et al, 2007; De Schutter & Vanden Abeele, 2010; Gerling et al. 2010; 2011; Nap & IJsselsteijn, 2016) or on intergenerational games (see for more information Costa & Veloso, 2016; Zhang & Kaufman, 2016; De la Hera et. al., submitted and Loos et al., submitted a/b).

In 2009, Nap et al. stated in their paper 'Senior gamers: Preferences, motivations and needs' that:

> Digital games hold the potential to enhance seniors' leisure time and social connectedness, and provide a mental and even physical workout. However, most digital games that are currently on the market are targeted at the younger audience and contain content that generally does not resonate well with seniors. Senior gamers do exist, yet little is known about them. (p. 247)

Two years later, De Schutter (2010) argued that "Studies with an emphasis on the older audience of digital games (Copier, 2002; Pearce, 2008) are still rare." (p. 156) Table 2.3 clearly shows that, as far as exergames being played by older adults is concerned, the situation has changed since 2009: numerous studies have since been conducted that provide insight into the different ways playing exergames impacts on the wellbeing of seniors:

Table 2.3. Studies on the effects of exergames on older people's …

Physical constitution	Van Schaik et al., 2008; Shubert, 2010; Aarhus et al., 2011; Brox et al., 2011; Sirkka et al., 2012); Anguera et al., 2013; Larsen et al., 2013; Heuvelink et al., 2014a; Bleakley et al., 2015; Kahlbaugh et al., 2011; Pompeu et al., 2012; Taylor et al., 2012
Cognition / Dementia / Alzheimer / Parkinson	Anderson-Hanley et al., 2012 ; Connolly et al., 2012; Kueider et al., 2012; Pompeu et al., 2012; Taylor et al., 2012; Cancela et al., 2014; Heuvelink et al., 2014a; Bleakley et al., 2015; Cutler et al., 2016; Schell & Kaufman, 2016
Psychosocial condition	Homma, 2009; Jung et al., 2009; Kahlbaugh et al., 2011; Sirkka et al., 2012; Chesler et al., 2015; Schell et al., 2016
Balance	Clark & Kraemer, 2009; Studenski et al., 2010; Agmon et al., 2011; Schoene et al., 2011; Kwok et al., 2011; Yamada et al., 2011; Bateni, 2012; Pluchino et al., 2012; Pluchino et al., 2012; Taylor et al., 2012; Janssen et al., 2013); Omholt & Waerstad, 2013; Pisan et al., 2013; Schoene et al., 2013; Van Diest et al., 2013; Heuvelink et al., 2014a; Beaulieu-Boire et al., 2015
Rehabilitation	Burke et al., 2009; Kwok et al., 2011; Laver et al., 2011; Taylor et al., 2012; Marston & Smith, 2012; Sirkka et al., 2012; Heuvelink et al. (2014a)

In order to present a compact overview of the degree of evidence based impact of playing exergames on older adults' wellbeing, we made use of 9 literature reviews published in this field (Table 2.4) and a systematic review of systematic reviews (Kari, 2014).

Table 2.4. Literature reviews on the impact of playing exergames on older people

	Number of studies	Medium	Impact on …	Evidence based?

1. Plow et al. (2011)	Scoping Review 25 studies	Exergames	"In spite of the promising potential of exergaming technology to increase health and function, improve rehabilitation services and decrease rates of inactivity in adults with systemic disabling conditions, we found that research on exergaming using affordable technology platforms is still in its infancy. The lack of pervasiveness of exergaming in the rehabilitation literature is probably in part because affordable technology platforms have only become readily available over the last couple of years."	"Only four studies employed a randomized controlled trial design and most studies were classified in the consideration-of-concept stage, according to Dobkin's framework. Few studies were comprehensive in their usability assessment."
2. Hall et al. (2012)	Systematic Literature Review 13 studies	Digital Video Games	"Digital games for older adults have been studied for use in rehabilitation treatments, physical activity promotion, mental acuity exercises, and increased social exchanges. The vast majority of reviewed studies revealed positive health outcomes for older adults associated with digital videogame play, especially related to mental and physical health benefits." (p. 408)	"Significant mental health outcomes of digital game interventions were found in the majority of the reviewed studies, followed by physical and lastly social health outcomes in older adults." (p. 402)

3. Marston & Smith (2012)	Narrative Review 37 studies (26 commercial and high end-lab based	Interactive Videogame Technologies	"Positive results show the use of off-the-shelf or specifically designed games and technology for rehabilitation can have an effective result in reducing physical and cognitive impairments within the community that are barriers to continuing and leading and independent life." (p. 149) "A mixed response was presented for using the Wii and PlayStation for stroke rehabilitation, identifying that patients preferred to interact with the PlayStation, utilizing natural body movement, more so than the Wiimote." (p. 149) "Overall, the reviewed studies found positive effects of game play on mental health status." (p. 150) "A mixed response of using videogame technology in conjunction with conventional therapy was identified from patients who demonstrated further assistance was required (from the therapist/spouse) to operate the equipment during the session." (p.150) "(…) a positive identification has been demonstrated between videogame technologies and fall rehabilitation. Validating the DDR as an assessment tool for falls has demonstrated the dance mat to be reliable." (p.150)	n/a

4. Bleakley et al. (2015)	Systematic Review 12 studies	Physically Based Interactive Computer Games (ICGs)	Examination of the physical and cognitive effects of physically based interactive computer games (ICGs) in older adults. "(…) ICG interventions varied in terms of software, game type, and nature of the computer interaction. Although there was preliminary evidence that ICG is a safe and effective exercise intervention for older adults, the dearth of high-quality evidence limits this finding. (…) ICG could be improved further by tailoring interventions for older adults; in particular, they should aim to optimize participant safety, motivation, and enjoyment for this population." (p. 1)	Dearth of high-quality evidence limits the finding. preliminary evidence that ICG is a safe and effective exercise intervention for older adults. "No major adverse effects were reported and two studies reported minor events." (p. 20)
5. Larsen et al. (2013)	Systematic Literature Review 7 studies (RCTs)	Exergames for healthy elderly	"Six of the seven studies found a positive effect of exergaming on the health of the elderly. However, the variation of intervention approaches and outcome data collected limited the extent to which studies could be compared." (p. 205)	"(…) exergames have a potential to improve physical health in the elderly. However, there is a need for additional and better-designed studies that assess the effectiveness and long-term adherence of exergames designed specifically for the elderly." (p. 205)

6. Hall & Marston (2014)	Review of primarily reviews (narrative and systematic) 36 studies	Digital Health Games	"The exponential growth of new gaming technologies, platforms, and sensors, the increased population of older adults who play digital games, the prevalence of chronic diseases, and the aging of the population provide exciting opportunities for researchers to find novel solutions through digital games to foster healthy aging. In summary, digital games are being studied for use as rehabilitation tools, as mental exercise tools, for physical activity promotion, and for increased social exchanges among older adults." (p .6)	n/a
7. Miller et al. (2014)	Systematic Review 14 studies	Virtual Reality (VR) and Gaming System	"Feasibility was inconsistently reported in studies. Where feasibility was discussed, strong retention (≥70%) and adherence (≥64%) was reported. Initial assistance to use the technologies, and the need for monitoring exertion, aggravation of musculoskeletal symptoms and falls risk were reported." (p. 188)	"Existing evidence to support the feasibility and effectiveness VR/ gaming systems use by older adults at home to enable physical activity to address impairments, activity limitations and participation is weak with a high risk of bias. The findings of this review may inform future, more rigorous research." (p.188)
8. Cota & Ishitina (2015)	Systematic Literature Review 37 studies	Digital Games	"We (…) found out that digital games is as an important resource in the fight against the elderly restrictions due to aging, supporting, for example, the treatment of diseases related to cognitive, physical and psychological aspects." (p. 2)	n/a

9. Marston et al. (2016)	Scoping Review 46 studies		"Existing evidence demonstrates the paucity of studies engaging older adults 85 years of age and above regarding the use of digital gaming and highlights a new understudied cohort for further research focus. Recommendations for future research include intentional recruitment and proportionate representation of participants ≥85 years of age, large sample sizes, and explicit mention of specific numbers of participants ≥85 years of age, which are necessary to advance knowledge in this area. Integrating a rigorous and robust mixed-methods approach including theoretical perspectives would lend itself to further in-depth understanding and knowledge generation in this field." (p. 1)	n/a

The results of the literature reviews in the Table above show that there are indications that playing exergames affects older adults' physical wellbeing and in our opinion, Larsen et al. (2013) were correct when they asserted that "Exergames have a potential to improve physical health in the elderly. However, there is a need for additional and better-designed studies that assess the effectiveness and long-term adherence of exergames designed specifically for the elderly." (p. 205) Kari (2014), who conducted a systematic review of systematic reviews in this field, draws the same conclusion:

> The results indicate that exergaming is generally enjoyed and can evoke some benefits for physical fitness and physical activity, but the current evidence does not support the ability of exergaming to increase physical fitness or physical activity levels sufficiently for significant health benefits. This systematic review also revealed several gaps in previous research. Additional high-quality research and systematic reviews concerning exergaming are needed. (p. 59)

We conclude this section with three remarks:

1. Aarhus et al. (2011) state that

> The computer game may diminish dedication to rehabilitation or physical training, since the physical movements of the individual are selected for game performance, rather than following a physical training programme: for instance, if a person has one weak shoulder, he or she could use the other shoulder to complete the game (p. 118).

If we want to find out about the impact of exergames on older people's wellbeing, we need experiments comparing the effects of exergames with the conventional approaches of exercise therapy. Studies such as the ones conducted by Kwok et al. (2011), Laver et al. (2011), Bateni (2012) and Pluchino et al. (2012) are good examples of such experiments. They conclude:

> The study is the first randomised control trial using the Nintendo Wii as a rehabilitation modality investigating a change in fall efficacy and self-reported falls. (…) The WiiActive game is beneficial for the older person with strength, cardiovascular, balance and coordination exercises (…). The band exercises may be more readily accepted as compared to stack weights and free weights. (Kwok et al., 2011, p.1)

> The usefulness of the Wii Fit as a therapy tool with hospitalised older people is limited not only by the small proportion of older people who are able to use it, but by older people's preferences for traditional approaches to therapy. Mainstream media portrayals of the popularity of the Wii Fit with older people may not reflect the true acceptability in the older hospitalised population. (…) (Laver et al., 2011, p. 1)

> Wii Fit training appears to improve balance. However, physical therapy training on its own or in addition to Wii Fit training appears to improve balance to a greater extent than Wii Fit training alone. (Bateni, 2012, p. 211)

> The video game balance board program, which can be performed at home, was as effective as Tai Chi and the standard balance exercise program in improving postural control and balance dictated by the force plate postural sway and DP measures. This finding may have implications for exercise adherence because the at-home nature of the intervention eliminates many obstacles to exercise training. (Pluchino et al., 2012, p. 1138)

2. It would also be interesting to conduct empirical studies focusing on older adults at a really high age, to see the effects of playing exergames on their wellbeing. To our knowledge, the scoping review conducted by Marston et al. (2016) is the only one focusing on older adults aged 85 and older.

3. Although there are a considerable number of studies that provide insight into the effects of exergames on the wellbeing of older adults, they often fail to offer insight into how older adults experience playing such games in natural settings: their voices cannot be heard. The explorative study conducted by Quandt et al. (2009) based on explorative interviews with older adults playing social games is an exception and a good example of how to gain insight into "the integration of gaming into their everyday life, and aspects of social interaction within real and virtual life" (p. 27): *I take care that it (the gaming) doesn't take too long. During the week, I have to get up early, half past six. And I also need some sleep! On the weekends, it depends on our (the family's) plans. If we go on a trip, then there's no gaming. Sometimes, on the afternoons or in the evenings, if there's nothing else happening, then one can sit there and keep at it.* (Interview Ralph) (pp. 41-42)

3. Conclusions and implications for future research

1. Are older adults *willing to* play exergames?

Older adults are certainly willing to play exergames. Not only do statistical data from countries such as USA, Norway, Sweden, Denmark and the Netherlands clearly show that a considerable number of older adults play digital games, our narrative literature review also shows which dimensions stimulate older adults to play exergames: diversion, social interaction and user friendliness.

2. Are older adults *able to* play exergames?

While older adults are definitely *able to* play exergames, game designers, who are often relatively younger, should take into account age-related functional limitations due to declining vision, useful field of view, hearing, visual motor-coordination and cognition. De la Hera et al. (submitted) offer a specific example of how the problem of decreased speed could be countered by suggesting that "in-game adjustable speeds might be an option to support older players for whom time-restricted games are a challenge (Nap et al., 2009)."

3. What is the *impact* of playing exergames on older adults' *wellbeing*?

On the one hand are empirical studies that show that playing exergames could – to a certain degree – have a potential impact on older adults' physical wellbeing. On the other hand, we conclude that we need (1) more evidence-based studies, to assess the effectiveness of exergames and older adults' long-term adherence to playing them and (2) qualitative studies giving voice to the experiences of older adults playing exergames in natural settings.

Future research should also pay attention to differences in the group of older adults (e.g., age, gender, education) and compare the impact of exergames versus traditional approaches on the wellbeing of older adults. We agree with Kari et al. (2012) who argue that:

(…) it seems that the exergaming industry still has a long way to go before exergames are perceived interesting enough in terms of the gaming experience and useful enough in terms of their effects on physical fitness. Therefore, it is critical that the exergaming industry concentrates on addressing these issues both in the game design and marketing of exergames. Ways that might aid in addressing these issues could be to design exergames that are more physically demanding, as this could result in them being perceived as more useful and, at the same time, also as more interesting. But they should not be designed physically too demanding as this might result in the games not being perceived fun enough. It might also be worthy to bring out the potential physical benefits of playing exergames in their marketing. Overall, finding the equilibrium between the hedonic and utilitarian aspects of playing exergames and delivering this message to potential customers seem to be the main challenges facing the exergame designers and the exergaming industry today and most probably also in the future. (pp. 11-12)

References

Aarhus, R., Grönvall, E., Larsen, S. B., & Wollsen, S. (2011). Turning training into play: Embodied gaming, seniors, physical training and motivation. *Gerontechnology*, *10*(2), 110-120.

Aarts, J., & Nøhr, C. (2010). Use of "serious health games" in health care: a review. *Information Technology in Health Care: Socio-Technical Approaches 2010: From Safe Systems to Patient Safety*, *157*, 160.

Agmon M., Perry, C. K., Phelan, E., Demiris, G,, & Nguyen, H.Q (2011). A pilot study of Wii Fit exergames to improve balance in older adults. *Journal of Geriatric Physical Therapy, 34* (4), 161-167.

Akrich, M. (1995). User representations: Practices, methods and sociology. In *Managing technology in society. The approach of constructive technology assessment* (pp. 167-184). London: Pinter.

Anderson-Hanley, C., Arciero, P. J., Brickman, A. M., Nimon, J. P., Okuma, N., Westen, S. C., ... & Zimmerman, E. A. (2012). Exergaming and older adult cognition: a cluster randomized clinical trial. *American journal of preventive medicine*, *42*(2), 109-119.

Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., ... & Gazzaley, A. (2013). Video game training enhances cognitive control in older adults. *Nature*, *501*(7465), 97-101.

Bak, L., Madsen, A., Henrichsen, B., & Troldborg, S. (2012). *Danskernes kulturvaner 2012*. Copenhagen, Denmark: Danish Ministry of Culture.

Baranowski, T. et al. (2016). Games for Health for Children—Current Status and Needed Research. *Games for Health Journal, 5*(1), 1-12.

Barnett, A., Cerin, E., & Baranowski, T. (2011). Active video games for youth: a systematic review. *Journal of Physical Activity and Health*.

Bateni, H. (2012). Changes in balance in older adults based on use of physical therapy vs the Wii Fit gaming system: a preliminary study. *Physiotherapy*, *98*(3), 211-216.

Beaulieu-Boire, L., Belzile-Lachapelle, S., Blanchette, A., Desmarais, P. O., Lamontagne-Montminy, L., Tremblay, C., ... & Tousignant, M. (2015). Balance rehabilitation using Xbox Kinect among an elderly population: A pilot study. *Journal of Novel Physiotherapies*, *2015*.

Bergstrom, J. C. R., Olmsted-Hawala, E. L., & Bergstrom, H. C. (2016). Older adults fail to see the periphery in a Web site task. *Universal Access in the Information Society*, *15*(2), 261-270.

Biddiss E., & Irwin J. (2010). Active video games to promote physical activity in children and youth: a systematic review. *Archives of Pediatrics & Adolescent Medicine, 164*(7), 664-672.

Billis, A. S., Konstantinidis, E. I., Mouzakidis, C., Tsolaki, M. N., Pappas, C., &Bamidis, P. D. (201 A game-like interface for training seniors' dynamic balance and coordination (2010). In Panagiotis, D. Bamidis& Nicolas Pallikarakis, editors, *XII Mediterranean Conference on Medical and Biological Engineering and Computing 2010*, volume 29 of *IFMBE Proceedings* (691–694). Heidelberg: Springer.

Bleakley, C. M., Charles, D., Porter-Armstrong, A., McNeill, M. D., 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*(3), NP166-NP189.

Bogost, I. (2007). *Persuasive Games: The Expressive Power of Video Games*. Cambridge MA: MIT Press.

Bouma, H. (2000). Document and interface design for older citizens. In P. Westendorp, C. Jansen, & R. Punselie (Eds.), *Interface design & document design* (pp. 67-80). Amsterdam: Rodopi.

Brown, S. C., & Park, D. C. (2003). Theoretical models of cognitive aging and implications for translational research in medicine. *The Gerontologist, 43*(1), 57-67.

Brox, E., Luque, L. F., Evertsen, G. J., & Hernández, J. E. G. (2011, May). Exergames for elderly: Social exergames to persuade seniors to increase physical activity. In *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2011 5th International Conference on* (pp. 546-549). IEEE.

Burke, J. W., McNeill, M. D. J., Charles, D. K., Morrow, P. J., Crosbie, J. H., & McDonough, S. M. (2009, March). Serious games for upper limb rehabilitation following stroke. In *Games and Virtual Worlds for Serious Applications, 2009. VS-GAMES'09. Conference in* (pp. 103-110). IEEE.

Cancela, J., Pastorino, M., Arredondo, M. T., & Vera-Muñoz, C. (2014). State of the Art on Games for Health Focus on Parkinson's Disease Rehabilitation. In *The International Conference on Health Informatics* (pp. 13-16). Springer International Publishing.

Charness, N. (2001). Aging and communication: Human factors issues. In N. Charness, D. C. Parks, & B. A. Sabel. (Eds.), *Communication, technology and aging: Opportunities and challenges for the future* (pp. 1-29). New York: Springer.

Chesler, J., McLaren, S., Klein, B., & Watson, S. (2015). The effects of playing Nintendo Wii on depression, sense of belonging and social support in Australian aged care residents: a protocol study of a mixed methods intervention trial. *BMC geriatrics*, *15*(1), 1.

Clark, R., & Kraemer, T. (2009). Clinical use of Nintendo Wii™ bowling simulation to decrease fall risk in an elderly resident of a nursing home: A case report. *Journal of geriatric physical therapy*, *32*(4), 174-180.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661-686.

Copier, M. (2002). *Ouderen & games: Een kwalitatief onderzoek naar ouderen die digitale spellen spelen* [Older people and games: Qualitative research on olde r people playing digital games]. Heerlen, Maastricht: International Institute of Infonomics, Centrum voor Gender en Diversiteit in Maastricht.

Costa, L., & Veloso, A. (2016). "Being (Grand) Players: Review of Digital Games and their Potential to Enhance Intergenerational Interactions". *Journal of Intergenerational Relationships*, 14(1): 43-59.

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*(1), 2-16.

Cutler, C., Hicks, B., & Innes, A. (2016). Does digital gaming enable healthy aging for community-dwelling people with dementia? *Games and Culture*, *11*(1-2), 104-129.

Czaja, S. J., & Lee, C. C. (2007). The impact of aging on access to technology. *Universal Access in the Information Society*, *5*(4), 341-349.

Czaja, S. J. & Lee, C. C. (2009). Information technology and older adults. In A. Sears & J. E. Jacko (Eds.), *Human-computer interaction: Designing for diverse users and domains* (pp. 17-32). Boca Raton: CRC Press.

Daley, A. J. (2009). Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics*, *124*(2), 763-771.

De Bruin, P. D. E., Schoene, D., Pichierri, G., & Smith, S. T. (2010). Use of virtual reality technique for the training of motor control in the elderly. *Zeitschrift für Gerontologie und Geriatrie*, *43*(4), 229-234.

De la Hera, T., Loos, E. F., Simons, M, & Blom, J. (submitted). Exploring the possibilities of intergenerational digital gaming. A narrative literature review.

De Schutter, B. (2010). Never too old to play: The appeal of digital games to an older audience. *Games and Culture*, *6*(2), 155-170.

De Schutter B, Vanden Abeele, V. (2010). Designing meaningful play within the psycho-social context of older adults. Proceedings of the 3rd International Conference on Fun and Games, 84-93. ACM.

De Schutter, B., Brown, J. A., & Abeele, V. V. (2015). The domestication of digital games in the lives of older adults. *new media & society*, *17*(7), 1170-1186.

De Schutter, B., & Brown, J. A. (2016). Digital Games as a Source of Enjoyment in Later Life. *Games and Culture*, *11*(1-2), 28-52.

Diaz-Orueta, U., Facal, D., Nap, H. H., & Ranga, M. M. (2012). What is the key for older people to show interest in playing digital learning games? Initial qualitative findings from the LEAGE project on a multicultural european sample. *Games for health: Research, Development, and Clinical Applications*, *1*(2), 115-123.

ESA (2016) 2016 Essential Facts About The Computer And Video Game Industry

Fung, V., Ho, A., Shaffer, J., Chung, E., & Gomez, M. (2012). Use of Nintendo Wii Fit™ in the rehabilitation of outpatients following total knee replacement: a preliminary randomised controlled trial. *Physiotherapy*, *98*(3), 183-188.

Gerling, K. M., Schild, J., & Masuch, M. (2010, November). Exergame design for elderly users: the case study of SilverBalance. In *Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology* (pp. 66-69). ACM.

Gerling, K. M., Schulte, F. P., & Masuch, M. (2011, November). Designing and evaluating digital games for frail elderly persons. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology* (p. 62). ACM.

Gerling, K., De Schutter, B., Brown, J., & Allaire, J. (2015, October). Ageing playfully: advancing research on games for older adults beyond accessibility and health benefits. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play* (pp. 817-820). ACM.

Graves, L. E., Ridgers, N. D., Williams, K., Stratton, G., & Atkinson, G. T. (2010). The physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults. *Journal of physical activity & health*, *7*(3), 393-401.

Guy, S., Ratzki-Leewing, A., & Gwadry-Sridhar, F. (2011). Moving beyond the stigma: systematic review of video games and their potential to combat obesity. *International journal of hypertension*, *2011*.

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: Research, Development, and Clinical Applications*, *1*(6), 402-410.

Hall, A. K., & Marston, H. R. (2014). Gaming and Older Adults in the Digital Age of Healthcare. In J. van Hoof, G. Demiris, & E.J. Wouters, *Handbook of Smart Homes, Health Care and Well-Being.* Springer International Publishing Switzerland.

Heuvelink, A., De Groot, J., & Hofstede, C. (2014a). Let's Play. *Ouderen stimuleren tot bewegen met applied games.* TNO en Vita Valley.

Heuvelink, A., Tak, C. P. M., & Van Meeteren, N. L. U. (2014b). The Opinions of People in the Netherlands over 65 on Active Video Games: a Survey Study. Games for Health 2014.

Homma, R. (2009). *Effects of the Wii on the Physical and Psychosocial Condition of Older Adults in a Senior* (Doctoral dissertation, The State University of New York at Buffalo).

Hoppes, S., Hally, C., & Sewell, L. (2000). An interest inventory of games for older adults. *Physical & Occupational Therapy in Geriatrics*, *18*(2), 71-83.

Hoppes, S., Wilcox, T., & Graham, G. (2001). Meanings of play for older adults.*Physical & Occupational Therapy in Geriatrics*, *18*(3), 57-68.

Huizinga, J. (1950 [1938]). *Homo ludens: A study of the play element in culture.* Boston: Bacon Press.

IJsselsteijn, W., Nap, H. H., de Kort, Y., & Poels, K. (2007, November). Digital game design for elderly users. In *Proceedings of the 2007 conference on Future Play* (pp. 17-22). ACM.

Iversen, S. M. (2014). Play and Productivity: The Constitution of Ageing Adults in Research on Digital Games. *Games and Culture 11*(1-2), 7-21

Janssen, S., Tange, H., & Arends, R. (2013). A preliminary study of the effectiveness of exergame Nintendo ‘‘Wii Fit Plus’’ on the balance of nursing home residents. *Games for Health Journal*, 2, 89–95.

Jung, Y., Li, K. J., Janissa, N. S., Gladys, W. L. C., & Lee, K. M. (2009). Games for a better life: Effects of playing Wii games on the well being of seniors in a long-term care facility. In M. Ryan (Ed.), *Proceedings of the Sixth Australasian Conference on Interactive Entertainment* (article 5). Sydney, Australia: ACM.

Juul, J. (2012). *A casual revolution: Reinventing video games and their players*. Cambridge MA: MIT Press.

Kahlbaugh, P., Sperandio, A., Carslon, A., & Hauselt, J. (2011). Effects of playing Wii on well being in the elderly: Physical activity, loneliness, and mood. *Activities, Adaptation and Ageing, 35*, 331–344.\

Kari, T., Makkonen, M., Moilanen, P., & Frank, L. (2012). The habits of playing and the reasons for not playing exergames: Gender differences in Finland. *The 25th Bled eConference" eDependability: Reliable and Trustworthy eStructures, eProcesses, eOperations and eServices for the Future" Research Volume-17.-20.6. 2012 Bled, Slovenia (pp. 512-526).* Edited by U. Lechner, D. Wigand, & A. Pucihar.

Kari, T. (2014). Can Exergaming Promote Physical Fitness and Physical Activity?: A Systematic Review of Systematic Reviews. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS), 6*(4), 59-77.

Kaufman, D., Sauvé, L., Renaud, L., Sixsmith, A., & Mortenson, B. (2016). Older Adults’ Digital Gameplay Patterns, Benefits, and Challenges. *Simulation & Gaming*, 1046878116645736.

Kooiman, B., & Sheehan, D. D. (2015). Exergaming Theories: A Literature Review. *International Journal of Game-Based Learning (IJGBL)*, *5*(4), 1-14.

Kueider, A. M., Parisi, J. M., Gross, A. L., & Rebok, G. W. (2012). Computerized cognitive training with older adults: a systematic review. *PloS one*, *7*(7), e40588.

Kwok, B. C., Mamun, K., Chandran, M., & Wong, C. H. (2011). Evaluation of the Frails' Fall Efficacy by Comparing Treatments (EFFECT) on reducing fall and fear of fall in moderately frail older adults: study protocol for a randomised control trial. *Trials*, *12*(1), 155.

Larsen, L. H., Schou, L., Lund, H. H., & Langberg, H. (2013). The physical effect of exergames in healthy elderly—a systematic review. *Games forHealth Research, Development, and Clinical Applications, 2*(4), 205-212.

Laver, K., Ratcliffe, J., George, S., Burgess, L., & Crotty, M. (2011). Is the Nintendo Wii Fit really acceptable to older people?: a discrete choice experiment. *BMC geriatrics*, *11*(1), 64, 1-7.

LeBlanc, A. G., Chaput, J. P., McFarlane, A., Colley, R. C., Thivel, D., Biddle, S. J., ... & Tremblay, M. S. (2013). Active video games and health indicators in children and youth: a systematic review. *PLoS One*, *8*(6), e65351.

Lewis-Beck, M., Bryman, A. E., & Liao, T. F. (2003). *The Sage encyclopedia of social science research methods*. London: Sage.

Lieberman, D. A. (2006). Dance games and other exergames: What the research says. [Internal publication.] University of California, Santa Barbara, http://www.comm. ucsb.edu/ lieberman_ flash.htm

Loos, E. F. (2014). Designing meaningful intergenerational digital games. Proceedings of the International Conference on Communication, Media, Technology and Design, Istanbul, 46-51. April 24 - 26, 2014.

Loos, E. F. , & Zonneveld, A. (2016). Silver Gaming: Serious Fun for Seniors? In J. Zhou & G. Salvendy (Eds.), Human Aspects of IT for the Aged Population. Healthy and Active Aging, Second International Conference, ITAP 2016, Held as Part of HCI International 2016 Toronto, ON, Canada, July 17–22, 2016, Proceedings, Part II (pp. 330-341). Switzerland: Springer International Publishing.

Loos, E. F, Simons, M., De la Hera, T. & Gevers, D. (submitted a). Setting up and conducting the co-design of an intergenerational digital game.

Loos, E. F., Kubinsky, & Romero (submitted b). The misrepresentation of older players in the world of digital games: Grandparents trying to play a digital game.

Loos, E. F., & Romano Bergstrom, J. Older adults. (2014). In J. Romano Bergstrom, & A. J. Schall (Eds.), *Eye Tracking in User Experience Design* (pp. 313-329). Amsterdam etc.: Elsevier.

Lu, A. S., Kharrazi, H., Gharghabi, F., & Thompson, D. (2013). A systematic review of health videogames on childhood obesity prevention and intervention. *Games for Health: Research, Development, and Clinical Applications*, *2*(3), 131-141.

Lunn, D., & Harper, S. (2009). Senior Citizens and the Web. *Manchester: School of Computer Science*.

Marston, H. R., & Smith, S. T. (2012). Interactive Videogame Technologies to Support Independence in the Elderly: A Narrative Review. *Games for health: Research, Development, and Clinical Applications*, *1*(2), 139-152.

Marston, H. R., Freeman, S., Bishop, K. A., & Beech, C. L. (2016). A Scoping Review of Digital Gaming Research Involving Older Adults Aged 85 and Older.*Games for health journal*.

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*(2), 13-22.

Miller, K., Adair, B., Pearce, A., Said, C., Ozanne, E., & Morris, 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.

Nakajima, T., Lehdonvirta, V., Tokunaga, E., & Kimura, H. (2008, February). Reflecting human behavior to motivate desirable lifestyle. In *Proceedings of the 7th ACM conference on Designing interactive systems* (pp. 405-414). ACM.

Nap, H., Kort, Y., IJsselsteijn, W. (2009). Senior gamers: Preferences, motivations and needs. *Gerontechnology, 8*(4), 247-262.

Nap, H., & IJsselsteijn, W. A. (2016). Design for senior gamers. *Gerontechnology* 15 (suppl): 134s

Neufeldt, C. (2009). Wii play with elderly people. *Enhancing Interaction Spaces by Social Media for the Elderly*, *6*(3), 50-59.

Nordicom-Sverige. (2012). *De fo¨rsta resultaten fra Nordicom-Sveriges mediebarometer 2012*. Göteborg, Sweden: Nordicom-Sverige.

Oh Y., & Yang S. (2010). Defining exergames and exergaming. In *Proceedings of Meaningful Play*, 1-17.

Omholt, K. A. & Waerstad, M. (2013). Exercise Games for Elderly Peope. Identifying important aspects, specifying system requirements and designing a concept. Unpublished Master thesis. Norwegian University of Science and Technology, Department of telematics.

Oudshoorn, N., Rommes, E., & Stienstra, M. (2004). Configuring the user as everybody: Gender and design cultures in information and communication technologies. *Science, Technology & Human Values*, *29*(1), 30-63.

Papastergiou, M. (2009). Exploring the potential of computer and video games for health and phsyical education: A literature review. *Computers & Education, 53*(3), 603-622

Pearce, C. (2008). The truth about baby boomer gamers a study of over-forty computer game players. *Games and Culture, 3*(2), 142-174.

Peng, W., Crouse, J. C., & Lin, J. H. (2012). Using Active Video Games for Physical Activity Promotion A Systematic Review of the Current State of Research. *Health Education & Behavior*, *40*(2), 171-192.

Pisan, Y., Marin, J. G., & Navarro, K. F. (2013, September). Improving lives: using Microsoft Kinect to predict the loss of balance for elderly users under cognitive load. In *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death* (p. 29). ACM.

Plow, M. A., McDaniel, C., Linder, S., & Alberts, J. L. (2011). A scoping review of exergaming for adults with systemic disabling conditions. *Journal of Bioengineering & Biomedical Science*.

Pluchino, A., Lee, S. Y., Asfour, S., Roos, B. A., & Signorile, J. F. (2012). Pilot study comparing changes in postural control after training using a video game balance board program and 2 standard activity-based balance intervention programs. *Archives of physical medicine and rehabilitation*, *93*(7), 1138-1146.

Pompeu, J. E., dos Santos Mendes, F. A., da Silva, K. G., Lobo, A. M., de Paula Oliveira, T., Zomignani, A. P., & Piemonte, M. E. P. (2012). Effect of Nintendo Wii™-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: A randomised clinical trial. *Physiotherapy*, *98*(3), 196-204.

Primack, B. A., Carroll, M. V., McNamara, M., Klem, M. L., King, B., Rich, M., & Nayak, S. (2012). Role of video games in improving health-related outcomes: a systematic review. *American journal of preventive medicine*, *42*(6), 630-638.

Quandt, T., Grueninger, H., & Wimmer, J. (2009). The gray haired gaming generation: Findings from an explorative interview study on older computer gamers. *Games and Culture*, 27-46.

Ruggiero, T. E. (2000). Uses and gratifications theory in the 21st century. *Mass communication & society*, *3*(1), 3-37.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological review*, *103*(3), 403.

Salthouse, T. A. (2004). What and when of cognitive aging. *Current Directions in Psychological Science*, *13*(4), 140-144.

Schell, R., Hausknecht, S., Zhang, F., & Kaufman, D. (2016). Social benefits of playing Wii Bowling for older adults. *Games and Culture*, *11*(1-2), 81-103.

Schell, R., & Kaufman, D. (2016). Cognitive Benefits of Digital Games for Older Adults - Strategies for Increasing Participation. In Proceedings of the 8th International Conference on Computer Supported Education (CSEDU 2016) - Volume 2 (pp. 137-141) Scitepress – Science and Technology Publications.

Schoene, D., Lord, S. R., Verhoef, P., & Smith, S. T. (2011). A novel video game–based device for measuring stepping performance and fall risk in older people. *Archives of physical medicine and rehabilitation*, *92*(6), 947-953.

Schoene, D., Lord, S. R., Delbaere, K., Severino, C., Davies, T. A., & Smith, S. T. (2013). A randomized controlled pilot study of home-based step training in older people using videogame technology. *PloS one*, *8*(3), e57734.

Schueren, B. (1986). Can decline in intellectual functioning be reversed? *Developmental* Psychology, 22, 223-232.

Sherry, J. L., Lucas, K., Greenberg, B. S., & Lachlan, K. (2006). Video game uses and gratifications as predictors of use and game preference. *Playing video games: Motives, responses, and consequences*, 213-224.

Shubert, T. E. (2010). The use of commercial health video games to promote physical activity in older adults. *Annals of long-term care*, *18*(5), 27-32.

Sirkka, A., Merilampi, S., Koivisto, A., Leinonen, M., & Leino, M. (2012). User experiences of mobile controlled games for activation, rehabilitation and recreation of elderly and physically impaired. *Studies in health technology and informatics*, *177*, 289.

Skalsky Brown, J. A. (2014). Let's Play: Understanding the Role and Significance of Digital Gaming in Old Age. *Theses and Dissertations--Gerontology.* Paper 6. http://uknowledge.uky.edu/gerontol_etds/6

Skalsky Brown, J. A. (forthcoming). Digital Gaming Perceptions Among Older Adult Non-Gamers. In J. Zhou & G. Salvendy (Eds.), Human Aspects of IT for the Aged Population. Healthy and Active Aging, Third International Conference, ITAP 2017, Held as Part of HCI International 2017 Vancouver, Canada, July 9-14, 2017, Proceedings. Switzerland: Springer International Publishing.

Smith, M. W., Sharit, J., & Czaja, S. J. (1999). Aging, motor control and the performance of computer mouse track. *Human Factors, 41*(3), 389-397.

Studenski, S., Perera, S., Hile, E., Keller, V., Spadola-Bogard, J., & Garcia, J. (2010). Interactive video dance games for healthy older adults. *The journal of nutrition, health & aging*, *14*(10), 850-852.

Taylor, L. M., Maddison, R., Pfaeffli, L. A., Rawstorn, J. C., Gant, N., & Kerse, N. M. (2012). Activity and Energy Expenditure in Older People Playing Active Video Games. *Archives of physical medicine and rehabilitation*, *93*(12), 2281-2286.

Theng, Y. L., Dahlan, A. B., Akmal, M. L., & Myint, T. Z. (2009, April). An exploratory study on senior citizens' perceptions of the Nintendo Wii: the case of Singapore. In *Proceedings of the 3rd International Convention on Rehabilitation Engineering & Assistive Technology* (p. 10). ACM.

Vaage, O. (2012). *Norsk mediebarometer 2012*. Oslo, Norway: Statistics Norway.

Van Diest, M., Lamoth, C. J., Stegenga, J., Verkerke, G. J., & Postema, K. (2013). Exergaming for balance training of elderly: state of the art and future developments. *Journal of neuroengineering and rehabilitation*, *10*(1), 1.Whitcomb, G. R. (1990). Computer games for the elderly. *ACM Sigcas Computers and Society*, *20*(3), 112-115.

Van Schaik, P., Blake, J., Pernet, F., Spears, I., & Fencott, C. (2008). Virtual augmented exercise gaming for older adults. *CyberPsychology & Behavior*, *11*(1), 103-106.

Vasconcelos, A., Silva, P. A., Caseiro, J., Nunes, F., & Teixeira, L. F. (2012). Designing tablet-based games for seniors: The example of cogniplay, a cognitive gaming platform. In Proceedings of the 4th international conference on fun and games (FnG '12) (pp. 1–10). New York, NY, USA: ACM.

Vercruyssen, M. (1997). Movement control and speed of behavior. In A. D. Fisk, & W. A. Rogers (Eds.), *Handbook of Human Factors and the Older Adult* (pp. 55-86). San Diego CA: Academic Press.

WHO (2012a). Health topics: Physical activity. Retrieved from http://www.who.int/topics/physical_activity/en/

WHO (2012b). Global Strategy on Diet, Physical Activity and Health: Physical Activity. Retrieved from http://www.who.int/dietphysicalactivity/pa/en/index.html

Wollersheim, D., Merkes, M., Shields, N., Liamputtong, P., Wallis, L., Reynolds, F., & Koh, L. (2010). Physical and psychosocial effects of Wii video game use among older women. *International Journal of Emerging Technologies and Society*, *8*(2), 85-98.

WHO. (2012a). Health topics: Physical activity. Retrieved from http://www.who.int/topics/physical_activity/en/

WHO. (2012b). Global Strategy on Diet, Physical Activity and Health: Physical Activity. Retrieved from http://www.who.int/dietphysicalactivity/pa/en/index.html

Williams, D., Martins, N., Consalvo, M., & Ivory, J. D. (2009). The virtual census: Representations of gender, race and age in video games. *New Media & Society*, *11*(5), 815-834.

Yamada, M., Aoyama, T., Nakamura, M., Tanaka, B., Nagai, K., Tatematsu, N., ..., & Ichihashi, N. (2011). The reliability and preliminary validity of game-based fall risk assessment in community-dwelling older adults. *Geriatric Nursing*, *32*(3), 188-194.

Zhang, F., & Kaufman, D. (2016). A review of intergenerational play for facilitating interactions and learning. *Gerontechnology*, *14*(3), 127-138.

Zonneveld, A. (2013). Wat beweegt ouderen? Kwalitatief onderzoek naar het gebruik van exergames onder ouderen [What moves Older People? Qualitative Research on the Use of Exergames among Older People]. Unpublished Master thesis. Utrecht: Utrecht University School of Governance, the Netherlands.