Exergaming for Elderly: Subjective Experiences and Objective Movement Characteristics

Elise Klæbo Vonstad

2013-2014

Department of Medicine, Institute of Neuroscience

Norwegian University of Science and Technology

Acknowledgements

This thesis is the culmination of six years of higher education. Finally reaching this point marks the achievement of one of my most prominent goals, and it is therefore my outmost pleasure to present my thesis to you in its final form. The road has been bumpy, but at the same time highly educational and very enjoyable, and I have many people to whom I owe my gratitude. First and foremost I would like to thank Beatrix Vereijken, my supervisor, for being always helpful no matter how big or small a question, and for pointing me in the right direction the numerous times I got tangled up. Nina Skjæret also deserves thanks for being very helpful with both inspirational discussions and for great assistance in the writing process. Xianchung Tan deserves thanks for assistance with technical issues in the movement laboratory, and for brilliant help with the data analysis. To my fellow students: thank you for these months of excitement, frustration, procrastination and progress.

I would also like to sincerely thank my participants for partaking in the project, without you this would not be possible. To my family and to my Malin I am also deeply thankful, for them always being there and for listening to me talk/rant endlessly about every detail of this project.

To anyone doing research, what I truly have learned throughout these years and my best advice to you:

Just keep swimming. - Dori, "Finding Nemo"

At the end, thanks to you, reader. If you are reading this line, you at least read one page of my thesis. Thank You.

Abstract

Background: It is important for elderly to stay healthy and independent for as long as possible, and falls are a major cause for loss of independence. Physical activity aimed at improving balance that includes large movements and cognitive tasks has been shown to decrease fall risk. Using exergames as a training tool has increased in recent years, but the actual movements elicited by such exergames have yet to be investigated objectively.

Aim: To investigate usability and enjoyment and provide objective quantification of movement size elicited by two exergames.

Methods: Twenty healthy elderly (mean age 74.4, range 65-90) played two exergames, The Mole (SilverFit) and LightRace (YourShape: Fitness Evolved) at easy and medium level, with five trials of one minute at each level. Data on perceived exertion (BORG), enjoyment and system usability (SUS) was collected.. Movements were captured using OQUS Motion Capture System, with passive reflexive markers attached to the base of the 1st toe, heel and lumbar area of the back. Movement size was expressed as Interquartile range (IQR) of feet and trunk in all three directions, and as horizontal area covered by the lumbar and toe markers. Correlational analyses were performed to investigate relationships between game scores, BORG-scores, SUS-scores, IQR and area coverage. Repeated measures ANOVAs were used to analyze effects of game, level, and trial.

Results: Both games scored high on usability, and the elderly perceived the games as enjoyable, relevant as physical activity, and not very exhausting. Game scores increased across trials and decreased from easy to medium levels. Nevertheless, participants preferred the medium over the easy levels because of the increased cognitive challenge. IQR and area in the feet exceeded those in the trunk, especially in the medio-lateral direction. There were no significant correlations between game score and movement variables.

Discussion: The positive attitude from the participants is promising for future implementation of exergames into fall preventive exercises. However, the lack of correlations between game scores and movement variables indicate that although these exergames do not reward players for "cheating" movements; they have room for improvement concerning rewarding desired movements.

Keywords: older adults, exergames, movement characteristics, stepping.

Contents

Introduction

A predicted increase in the proportion of elderly in the population in the coming years has received much attention in media, policy making, and research. Because of the simultaneous decline in people working in the health care sector, there is a need for this new wave of elderly to stay healthy and independent for as long as possible, to minimize the time they spend dependent on health care (Sattin. 1992). This has obvious benefits both for the individual and for the society, which gives incentives to find methods of keeping the coming older generation healthy and independent for as long as possible.

Technological advances are making the monitoring of health status outside of doctors' offices and institutions, called Remote Patient Monitoring, increasingly reliable using sensors and mobile technology to collect and send health data such as blood pressure and glucose levels in addition to alarming care takers about potential falls (R.Y.W. Lee 2011, Raine 2012). Researchers have yet to establish what factors are most important in identifying future fallers before the first fall occurs, and despite extensive work on the matter there seems to be no clear solution due to the complexity of the risk factors for falling (Hausdorff, Rios et al. 2001, Tinetti. 2003). Experiencing a fall has a wide range of negative effects on the elderly, and 1/3 of persons over the age of 65 years fall each year (Tinetti. 2003). Injuries are the most severe physical effects, and often lead to hospitalization and even death (Kannus, Niemi et al. 2005). In addition, falling even without injury often results in increased fear of falling again (M. E.Tinetti 1994), which might cause the elderly to restrict mobility and inhibit activity (K. Uemura 2012, R. Sawa 2014), and increase the risk of becoming in need of health care earlier.

Previous research has indicated that physical activity is a key factor to the health status of elderly (A. Barnett 2003, Sherrington, Whitney et al. 2008, Gillespie, Robertson et al. 2013). Engaging in regular physical activity has been shown to have positive effects on health, both physically and mentally in the general population. This includes reduced risk of cardio-vascular disease (J. Lian 2013), multiple types of cancer (J. Kruk 2006), and musculoskeletal diseases (P.J. Mork 2012, P.J. Mork 2013, M.I. Carter 2014). Also, it has become clear that participating in physical activity groups is an important social arena for the elderly which in return is positive for quality of life (P. Prevc 2009). Furthermore, mental well-being is increased (G.F. Bertheussen 2011) and risk of depression and anxiety is reduced when people are in regular physical activity (A. Brunes 2013). With increasing age, the risk of developing severe neurodegenerative diseases like Alzheimer's disease or Parkinson's disease increases, and physical activity has shown to both reduce this risk (X-H.Wang 2002, A-M. Tolppanen 2014) and also slow down the degenerative process (J.C. Smith 2014, N. Farina 2014).

Physical effects of regular physical activity are well documented, including increased strength, endurance, and joint mobility. Furthermore, physical activities that include specific movements and exercises have been shown to have positive effects on the stabilizing abilities of elderly (Sherrington, Whitney et al. 2008).These movements are characterized by targeting specific qualities that are important in being able to maintain stability when faced with unexpected events or obstacles during dynamic activities, such as walking (Sherrington, Whitney et al. 2008). Weight transfer from one foot to the other is one of these qualities. The movement of one's center of mass (COM) in the anterio-posterior (A-P) direction and especially in the medio-lateral (M-L) direction is essential to maintaining stability, and research has shown decline in fall-prone elderly's ability to adjust their COM (Maki and McIlroy 2006, K.P.Granata 2008). Another quality is stepping responses (Maki and McIlroy 2006, I. Melzer 2010). These are important as they allow us to avoid obstacles and counter destabilizing events like tripping and slipping. Elderly have been shown to have impaired stepping responses when faced with external perturbations, by taking steps that do not adequately counter the destabilizing situation (C.A.Laughton 2003, Tseng, Stanhope et al. 2009). To be able to adapt to different kinds of external perturbations, stepping responses must additionally be performed in different sizes and directions (Maki and McIlroy 2006), as well as under dual-task conditions (I. Melzer 2004, Pichierri, Coppe et al. 2013).

One of the ways one might train these skills is through a form of physical activity that has emerged over the recent years with the introduction of movement-controlled video games from developers like Nintendo®Wii, Playstation®Move, and Microsoft®Kinect. Such exercise games, so-called exergames, are controlled by either moving wireless hand-held controllers, or by motion-sensing-cameras that pick up the players' movements from parts or from the whole body. To our knowledge, none of these commercial exergames or gaming systems has been developed for elderly specifically, although some have been developed for rehabilitative use and in institutions. Because these exergames propose an easily accessible, low-cost and enjoyable form of physical activity, they have been given increasing attention in health care and in rehabilitation in recent years (Lange, Physioa et al. 2010, Schoene, Lord et al. 2013), and results from intervention studies where exergames are used by seniors to engage in physical activity are promising (M. van Diest 2013). This is especially interesting for elderly, since these systems might be helpful in engaging elderly in physical activity that targets specific movements, for example stepping responses, without having to venture outside or being put at unnecessary risk of falling. However, the actual movements elicited when elderly play these exergames have not yet been quantified, which makes it hard to interpret the results of exergames interventions. Even though the exergames are developed with the purpose to make people move, there is to our knowledge no prior research investigating how people move while playing. It is likely that one finds ways to "cheat" by scoring points while moving just a little bit in just the right way, which would defeat the purpose of exergaming as a training form itself. Furthermore, there is little information about whether existing exergames actually are enjoyable and user friendly for the elderly, or whether they feel that exergaming is pointless and do not experience the exergames as useful regarding physical activity.

If exergames are to be used by clinicians and in health care institutions as a training tool, it is necessary to have more knowledge about how elderly perceive the exergames and what movement characteristics are elicited when playing exergames, to ensure that they actually are beneficial to specific purposes. *The aim of this study, then, is to investigate 1) subjective measures of system usability and enjoyment, and 2) objective measures of the movements elicited by two different stepping exergames.* Specifically, we investigated size of stepping responses and weight transfer as indicated by feet and trunk displacements, respectively.

Methods

Participants

Twenty elderly (8 men, 12 women) participated in the study. To be eligible to join the project the participants had to be 65 years or older, have no known physical and/or mental disabilities, and be able to walk safely without a walking aid. Participants were recruited from the municipality of Trondheim through recreational exercise groups. Participants were instructed to wear comfortable clothing and good walking shoes to minimize movement restriction during testing. The study was approved by the Regional Ethical Committee for Medical and Health Research Ethics.

Equipment

OQUS Motion Capture System (Qualisys AB, Gothenburg, Sweden) was used to record the movements of the participants. Seven infrared cameras were placed around the area where the exergames were played, and one digital video recorder was placed on the participants' right side (See Figure 2, Area Setup Overview). Cameras 2 and 6 were suspended from the roof, while all other cameras were placed on tripods, approximately 1.80 m above the ground. None of the cameras could be placed directly behind the participants because of interference with the gaming cameras, as both utilize infrared light. Sampling rate was 100 Hz, and all cameras were calibrated simultaneously prior to the arrival of each participant, with marker error distance < 1.0 mm. Passive reflexive markers were used, and these were attached with double-sided tape to the participants base of 1^{st} toe and heel on both feet and on the lumbar area of the back (see Figure 1).

An accelerometer application (uFall) on a Samsung Galaxy SII or Samsung Galaxy SIII was used to record the accelerations of the participants' movements in three directions. The smartphone was placed in a belt around the participants' waist in the lumbar area of the back.

Figure 1. Marker set-up. Red circle: toe marker right foot, blue circle: toe marker left foot, green circle: lumbar marker.

For the exergames we used an Xbox with a Kinect camera (Microsoft Inc), and a HP PC with a Soft Kinect camera from SilverFit (SilverFit BV, Woerden, The Netherlands). The XBox and PC were connected to a 36" ASUS screen, placed 2.5 meters in front of participants' starting position. Gaming cameras were placed 3 meters in front of the start position and 1.80 m up at an angle of 45° with the ground, in accordance with the setup manuals.

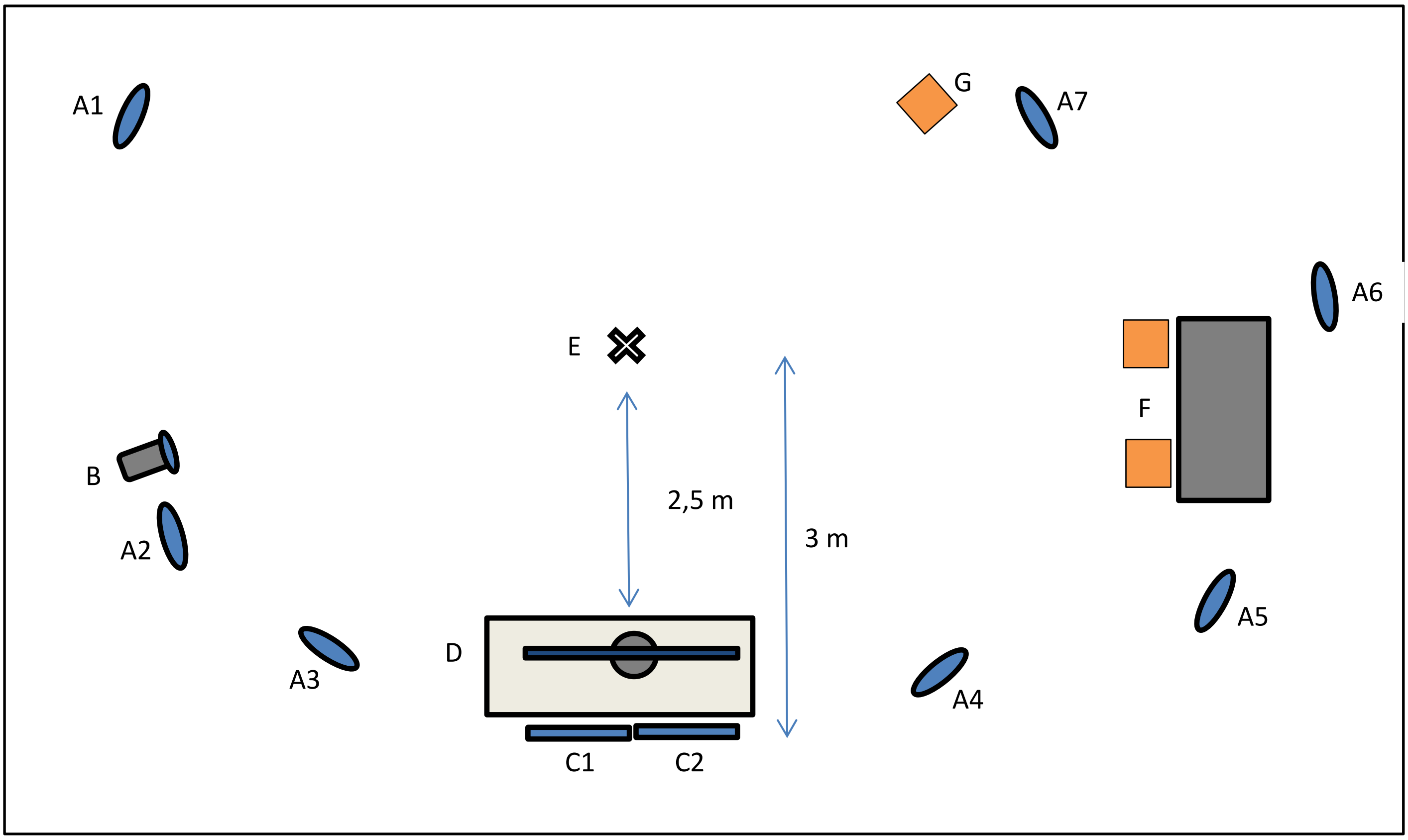

Figure 2. Area Overview. A 1-7: OQUS cameras, B: Video recorder, C1: Kinect camera, C2: SilverFit camera, D: ASUS screen (on table), E: Start position, F: Preparation/interview table, G: Break chair.

The Exergames

The choice of exergames in this study is based on an earlier observational study (Skjæret, Nawaz et al. 2013). Here, the three stepping exergames The Mole (Silverfit), LightRace (YourShape: Fitness Evolved) and Dance Dance Revolution (DDR) (www.stepmania.com) modified for elderly by Schoene et al 2009, were compared with respect to game elements and qualitative movement characteristics. They found that The Mole and LightRace elicited better movement characteristics than DDR and had better game elements. Also, since DDR required the players to stand on a dance mat on the floor, this game had increased risk of adverse events compared to The Mole and LightRace where the players stand directly on the floor. Skjæret et al. also found that these two exergames stimulated more visual independency from one's feet, which is an important factor in maintaining stability as it enables prospective control of movements (T. Mulder 2002), and therefore should be aimed for in physical activity for the elderly.

YourShape: Fitness Evolved (Ubi Soft Divertissement Inc., Montréal, Canada) is a game designed for physical activity in the general public on Xbox One (Microsoft Inc.), with a Kinect 3D Motion Sense camera. YourShape: Fitness Evolved consists of a variety of mini exergames, aimed at different types of physical activity. The game is calibrated to the individual player with body measurements taken before one can begin playing, and the game progress, including a calorie count, is saved for each user. The player is represented on the screen by a full-body 3D avatar that reflects the actual appearance of the player, and it tracks all body movements. In the main menu, the player can choose between Personal Training, Fitness Classes or Gym Classes. The minigame "LightRace" we are using is under the category "Gym Classes". The game elements consist of a white space where the player is situated in a transparent cylinder in the middle of the space (See Figure 3a). There is a fixed green circle on the floor; this is the gaming area in which the player must remain during game play in order for the camera to adequately detect the player's body. Also, there is a gray circle around the player on the floor. This moves with the player's body mass. The gray circle is divided into five sections; two in front of the player, one on each side and one behind the player. During the game these sections light up one by one by turning blue for a given amount of time, and the goal is to step on the blue section. If the player manages to hit the section within the given time frame, it turns green and an affirmative sound is played. A blue bar shoots up on the wall of the cylinder, indicating how fast the player managed to hit the target. One hit yields two points, but this score increases exponentially if the player hits multiple targets in a row, giving a maximal score of 10 points for one hit. If a player takes a misstep by hitting the wrong section or not hitting the target within the time frame, the section turns yellow, the score multiplier is reset, and a negative sound is played. If the player hits the targets quickly, the rate of how fast the sections turn blue increases. LightRace is divided into two difficulties: easy and medium. At the easy level, only the sections on the sides and in front of the player light up. At the medium level, the section behind the player can also light up, and the two sections on either side of the player might light up simultaneously. During the entire interaction with the game, there is an interactive Personal Trainer that comments on the players choices in the menus, and she also gives feedback on the players' performance during the exergames. The game is accompanied by fixed music.

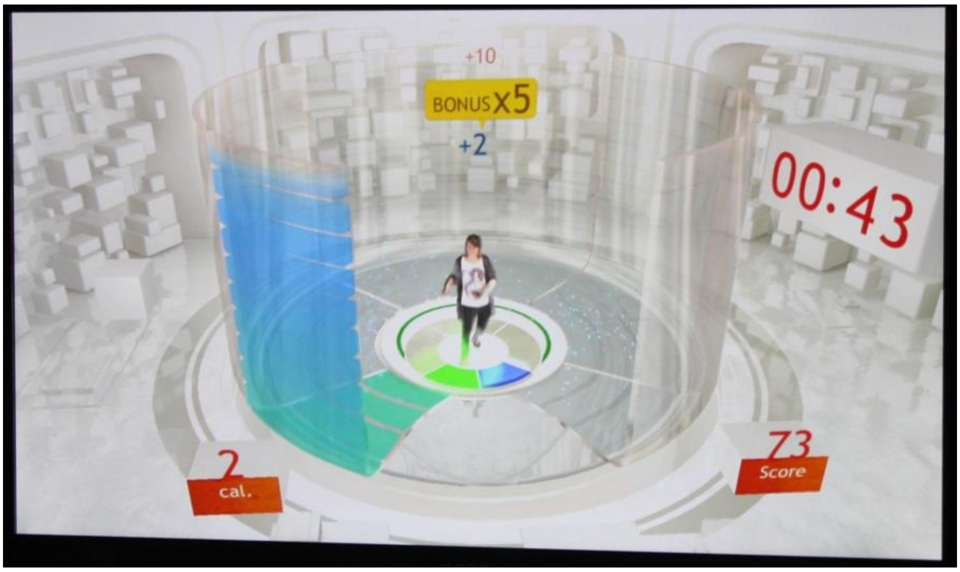

Figure 3a: LightRace.

SilverFit is a rehabilitation system made by SilverFit BV in the Netherlands (A. Rademaker 2009). The system consists of both hardware and software for PC, with exergames being specifically designed for senior citizens in supervised exercise or rehabilitation settings. A variety of different mini exergames are offered in the SilverFit software, which can be adjusted to the physical and cognitive level of the player. "The Mole" is one of many mini exergames available and is categorized as one of the exergames designed for balance training. Using a time-of-flight (ToF) 3D motion sensing camera, the player's movements are captured and represented on a screen in front of the player as a simplified "shoe print" of each foot. This happens in real-time, so the player can see where he/she is standing in relation to the gaming area at all times. The gaming area is 5x5 meters, and all gross body movements are traced in a 176x144 pixel array. The game elements consist of a 3x3 grid covering most of the screen, designed to resemble a natural green environment, with drawn targets that represent a gray mole, a gray mouse and a red ladybug (See Figure 3b). To hit a target one has to "step" on it by moving one foot or both feet to the area of the floor where the target appeared. Hitting a mole or a mouse yields one point each, while hitting a ladybug reduces the score by one. Positive targets (mole and mice) appear randomly and one at a time in any of the squares of the grid, and negative targets (ladybugs) randomly appear one or two at a time in all squares except the middle one. When moles appear they are present until they are hit; when a mouse appears it moves from one square to another and disappears when it reaches the next square or when hit; the ladybugs disappear after a given amount of time or when hit. A bar covering the right side of the screen shows how much time the player has left. If the player steps outside of the gaming area the game pauses until the person is detected by the camera again inside the gaming area. The game has two different versions: In the first, Basic or "easy", the only targets that appear are moles. In the second version, Precision Control or "medium", all targets appear: moles, mice and ladybugs. The game also has a multiplayer function where you play one round each and compare scores afterwards. The game does not have a narrator or music, but when a target is hit an affirmative sound is played if the target was positive and a different sound if the target was negative. The square the target appeared in also turns green if it was hit, independent of what the target was.

Figure 3b: The Mole.

Procedure

All tests were conducted at the movement laboratory at Dragvoll Idrettssenteret at NTNU, Trondheim. Upon arrival the participants were given oral and written information about the project and signed a consent form. The reflexive markers were placed on the feet and on the lower back and the waist belt was attached. The accelerometer application was started and the Samsung placed in the waist belt.

The order of the exergames the participants played was arranged in a counter-balanced manner (4 men and 6 women started with each of the two exergames), to remove any effects that the game order might have. All participants followed the same protocol:

Game 1, level 1

Introduction to game and easy level → try-out trial (No data recorded)

↓

5 one-minute recorded trials, one minute seated break between trials

↓

5 minute seated break → BORG-scale and interview questions

Game 1, level 2

Introduction to medium level → try-out trial (No data recorded)

↓

5 one-minute recorded trials, one minute seated break between trials

↓

5 minute seated break → BORG-scale and interview questions → SUS-form

The same protocol was repeated for the second game. One researcher stood behind the participants to ensure their safety while playing the exergames. After all trials were completed the reflexive markers and the waist belt were removed, and the accelerometer application was stopped.

After each gaming level (The Mole easy and medium, and LightRace easy and medium) the participants marked the BORG Perceived Exertion Scale ((Borg. 1998) Appendix I), where the subjective perception of effort when playing the exergames was marked on a scale from 6 (no exertion) to 20 (maximal exertion), and a small semi-structured interview was conducted, where the participant was asked the three questions "How did you like this game – was it fun?", "Were you afraid of falling while playing?" and "Can you see yourself use this game as a form of physical activity in your daily life?" (Appendix II). A second researcher registered the partipicants' responses.

After completing both levels for each of the exergames (The Mole and LightRace), the participants also filled in the System Usability Scale (SUS, Appendix III) where 10 statements about the game system were presented, and the participants marked to what extent they agreed or diagreed with each statement ranging from 1 “Strongly disagree” to 5 “Strongly agree”(Brooke. 1996). After finishing both exergames, the Falls Efficacy Scale – International (FES-I) (Delbaere, Close et al. (2009), Norwegian version, Appendix IV) was used to collect data on participants’ fear of falling by asking how worried participants were of falling on a scale of 1 (not worried at all) to 4 (very worried) when performing 16 different daily activities. The last questionnaire was a background questionnaire (Appendix V) consisting of questions about age, gender, work status, leisure time physical activity, number of daily perscription medications, previous falls, and previous exergaming experience. After all gaming conditions were finished, two functional test were performed: a six meter walking test (Guralnik. 1994) and a 30 seconds sit-to-stand test (R.E. Rikli 1999). Finally, height and weight were measured with a measuring stand and a scale, respectively.

Data Analysis

The overall amount of physical activity was calculated after coding the reported frequency and duration of physical activity during an average week (See Appendix V for the questionnaire). Frequency (sessions/week) was coded as follows: 0=0, 1=1.5, 2=2.5, 3=3.5, 4=4.5, 5=5.5, 6=7, and duration (min/session): 1=15, 2=45, 3=75, 4=105, 5=150, 6=200. Total minutes per week were calculated as frequency x duration, and total minutes per day as total per week/7. Intensity was categorized by how strenuous the activity they performed normally was: 1= not strenuous, 2= a little strenuous, 3= somewhat strenuous, 5= strenuous and 6= very strenuous.

SUS-scores were calculated as total usability across the 10 questions. As even number questions were negatives, these scores were converted and total scores calculated so that they ranged from 0 (low usability) to 100 (high usability). When yielding an average score of 68 or more, the system is considered to be of high usability (Brooke. 1996). Average total SUS-score was calculated separately for The Mole and LightRace.

Game scores were the total scores across each trial for both levels in LightRace and the Easy level for The Mole. For the medium level in The Mole, total score was the amount of moles hit plus the amount of mice hit minus the amount of ladybugs hit as these were negative points.

Accelerometer data are not included in the present analysis, as these data are not directly relevant for the aim of this study, but will be used later to help develop algorithms to be used in a planned RCT.

Due to restrictions on the placement of the OQUS cameras, heel markers were not always visible to at least two cameras. Therefore, analyses of OQUS data were restricted to the toe markers and the lumbar marker. We quantified size of stepping responses by calculating range of movement and area covered by the toe markers. Weight shift was quantified as the horizontal movement of the lumbar marker as a proxy for COM. Calculations were performed in medio-lateral (M-L), anterio-posterior (A-P), and vertical (for lumbar marker only) directions. Range (cm) was expressed as interquartile range (IQR) that included 75% of the marker positions. Area (cm^2) covered by toe and lumbar markers was calculated by fitting an ellipse to the total movement area. The directions of the two axes of the ellipse were computed by principal component analyses. The direction of the principal axis was the first eigenvector of the covariance matrix and the variance along this axis was the largest eigenvector. The second eigenvector was orthogonal to the first and formed the second axis of the ellipse. The length of each ellipse axis was subsequently set to 1.96 x SD along the principal components (L.F. Oliveira 1996). MatLab Version 22 (The MathWorks Inc., MA, US) was used for all calculations.

Statistical analysis

All data were normally distributed, enabling the use of parametric tests. Descriptive analyses were performed on participant characteristics. Game scores were analyzed using Three-Way repeated measures ANOVAs Game (2) by Level (2) by Trial (5). Independent samples t-tests were used to analyze the difference in game score, BORG-score and SUS-score depending on what game was played first. A paired-samples t-test was used to analyze the difference in SUS-scores between The Mole and LightRace. BORG data were first analyzed by Three-Way repeated measures ANOVAs Game (2) by Trial (5) by Gender (2). As there were no effects of Gender or interactions with Gender, Gender was not included in the final model, and data was further analyzed using Two-Way ANOVAs with repeated measures on Game and Level.

To test for possible associations between game scores, BORG, SUS-scores, movement areas and movement ranges, Spearman's correlation coefficients, ρ, were used. To analyze associations between game scores, movement areas and movement ranges, Pearson's correlation coefficients were used. One-Way repeated measures ANOVAs Trial (5) were used to analyze development of game scores over the five trials in both exergames and both levels. Four-Way repeated measures ANOVAs Game (2) by Level (2) by Trial (5) by BodyPart (2, lumbar and toe) were used to analyze movement area and IQR (in A-P, M-L and vertical direction separately). As there were no main effects of Trial or significant interactions with Trial, Trial was excluded in the final model, resulting in Three-Way repeated measures ANOVAs Game (2) by Level (2) by BodyPart (2). All statistical analyses were done in SPSS (IBM Statistics 20). Significance level was set to $p < 0.05$.

Results

Participant characteristics

The study sample consisted of twenty participants (8 males, 12 females), with a mean age of 75.7 years (SD±5.48, range 65-90). All participants were retired at the time of data collection. Participants' height, weight, BMI, number of daily prescription medications, and fear of falling are presented in Table 1.

Table 1. Participant characteristics. Age (years), height (cm), weight (kg), BMI (calculated as weight/height^2), number of different medications taken daily, FES-I (Total score), Sit-to-Stand 30 sec (number of chair rises in 30 seconds), walking speed (m/sec). P-values refer to independent-samples t-tests on gender.

	Mean (SD)	Range	p-value
Age	75.7 (±5.48)	65-90	.864
Height*	167.5 (±10.52)	152.0-184.5	**.000**
Weight*	74.5 (±9.81)	54.0-91.5	**.004**
BMI	26.6 (±3.30)	22.3-34.1	.238
Daily medication	2.0 (median: 1.5) (± 1.74)	0-7	.424
FES-I	19.5 (median: 19) (±2.81)	16-27	.532
Sit-to-stand 30 sec	14.6 (± 2.90)	8-19	.629
Walking speed	1.36 (±0.31)	0.52-1.76	.794

Abbreviations: BMI: Body Mass Index. FES-I: Falls Efficacy Scale International.
*Results with significant (p<0.05) gender differences

With respect to earlier falls, 12 of the participants (66.7 %) had not fallen during the previous year, five (27.8 %) had fallen once, and one (5.6 %) had fallen more than once but less than five times. All reported that falls had happened outside. Data on falls from 2 participants were missing.

Furthermore, the group consisted of mostly novice “exergamers”; 16 had never tried the current exergames or anything similar before, two had tried a similar game once, and one had tried it more than once but less than five times. The exergames they had tried were exergames designed for entertainment. Data from 1 participant was missing.

Table 2 presents the results on self-reported physical activity. As can be seen in the table, average total physical activity per day was 61.0 minutes (± 27.7); on average, the participants engaged in physical activity 5.63 (±1.55) times per week, for an average of 75.83 (±23.27) minutes. The average intensity was 2.39 (±0.60) on a scale from 1 (not strenuous) to 6 (very strenuous). Independent-samples t-tests indicated that there were no gender differences in physical activity ($p=.993$ for frequency, $p=.433$ for duration, and $p=.490$ for intensity).

Table 2. Frequency (times/week), duration (min), and intensity (1=very light, 2= slightly strenuous, 3= somewhat strenuous, 4= strenuous, 5= very strenuous) of self-reported physical activity, as well as total physical activity per day. There were no significant gender differences in any of the physical activity variables.

	Total (SD)	**N**	**Women (SD)**	**N**	**Men (SD)**	**N**
Frequency	5.63 (±1.55)	18	5.63 (±1.51)	11	5.64 (±1.72)	7
Duration	75.83 (±23.27)	18	72.2 (±16.18)	11	81.4 (±32.2)	7
Intensity	2.39 (±0.60)	18	2.27 (±0.64)	11	2.57 (±0.53)	7
Total PA/day*	61.0 (±27.7)	18	57.2 (±17.5)	11	66.8 (±39.9)	7

* In minutes, calculated as Frequency x Duration = total min/week, divided by 7.

Game scores

Overall, scores were higher at the easy level than at the medium level for both exergames. Furthermore, game scores slightly increased across trials in both exergames at both levels (Figure 4). Results from Three-Way repeated measures ANOVA Game (2) by Level (2) by Trial (5) showed significant main effects of Game ($F(1,17)=23.369$, $p<.001$), Level ($F(1,17)=8.121$, $p=.011$), and Trial ($F(4,68)=6.218$, $p<.001$). There was a significant interaction between Game and Trial ($F(4,68)=5.347$, $p=.001$), but not between Game and Level ($p=.192$), Level and Trial ($p=.107$) or Game, Level, and Trial ($p=.104$).

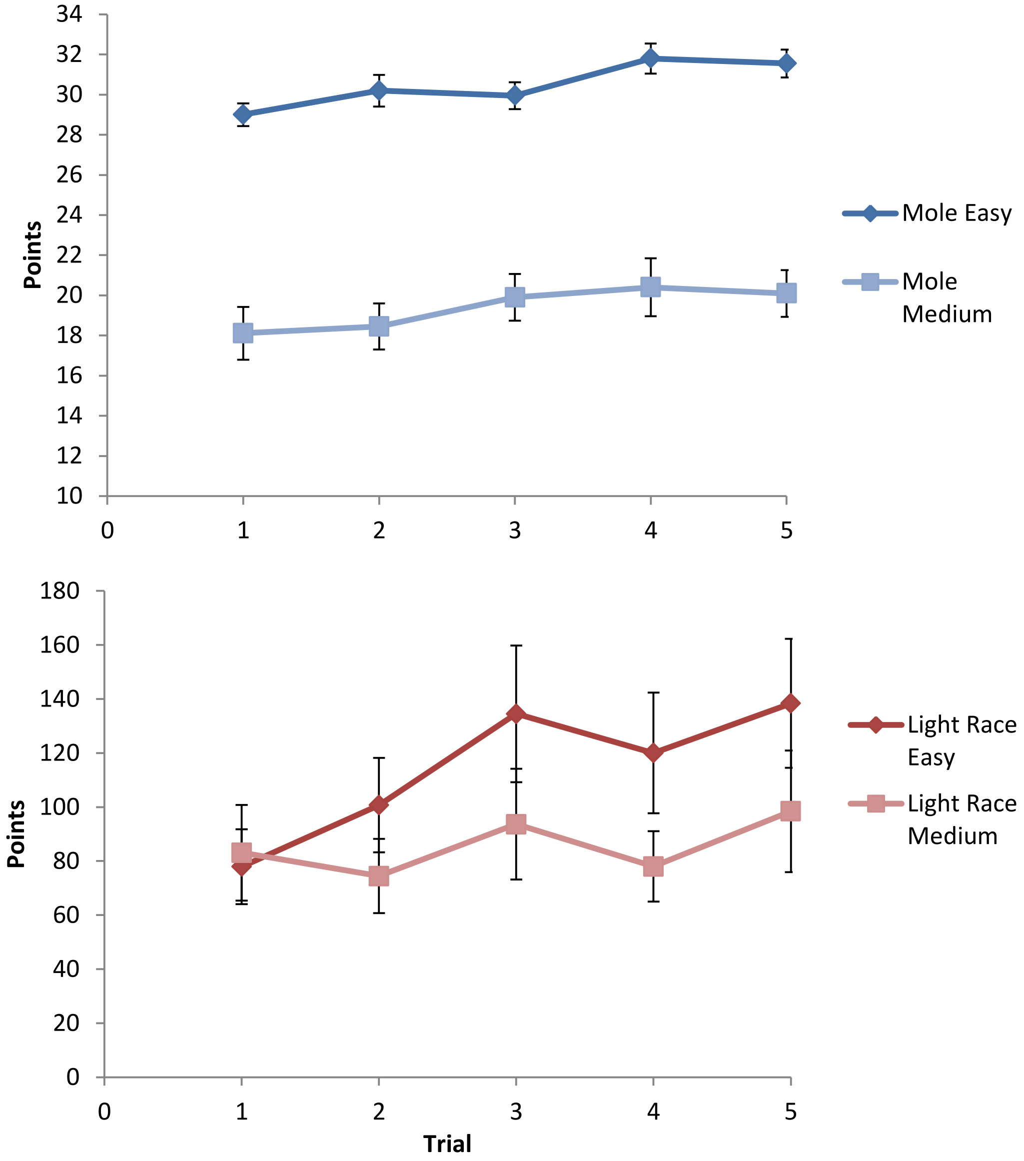

Figure 4. Development of game scores (with error bars, SE) over 5 trials in The Mole (top panel) and LightRace (bottom panel), at easy and medium level.

The Mole had a higher relative difference in scores between easy and medium level with 36.45 % lower scores at the medium level, while LightRace had 26.05 % lower scores at the medium level.

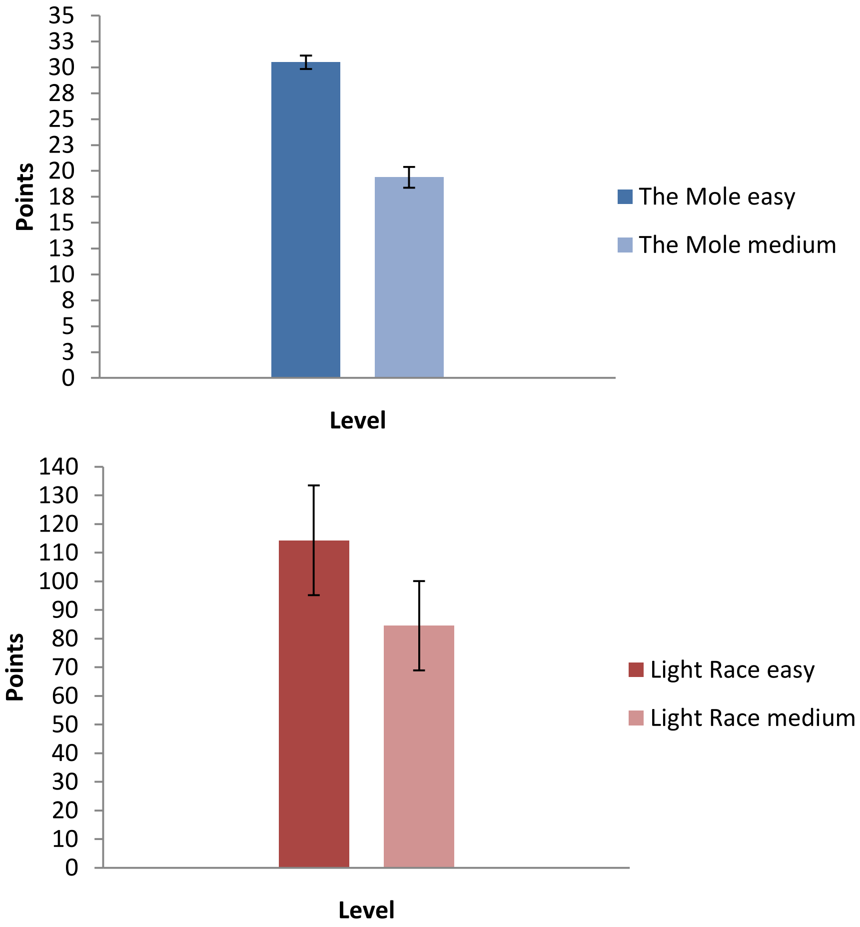

Figure 5. Mean game scores (with error bars, SE) across trials in each game and at each level: The Mole easy and medium (top panel), and LightRace easy and medium level (bottom panel).

When participants had played The Mole as the first game, game scores in both LightRace easy and medium level tended to be lower than for those participants who played LightRace as the first game: 34.66 (23.5 %) points lower for LightRace easy, and 35.36 (42.5 %) points lower for LightRace medium. However, independent samples t-tests indicated that these differences were not significant for LightRace easy (p=.380) or LightRace medium (p=.268). This influence was not seen to the same extent in the game score in The Mole for participants who played LightRace as the first game, although the game score was on average lower by 0.88 (2.8 %) points in The Mole easy and 2.1 points (11.36 %) in The Mole medium, but not significantly, with p=.323 for easy level and p=.110 for medium level.

Perceived exertion

Perceived exertion was indicated on a Borg-scale after each round of five trials. As can be seen in Figure 6, BORG-scores were slightly higher for LightRace than The Mole, and higher for the medium than the easy level in both exergames. Additionally, as can be seen in the figure, the scores are below 13 on the scale for both exergames and levels, which indicates medium to low perceived exertion. A Two-Way ANOVA with repeated measures on Game (2) and Level (2) indicated significant main effects of Game ($F(1,19)=8.680$; $p=0.009$) and Level ($F(1,19)=25.624$; $p<.0005$), but no significant interaction between Game and Level ($p=0.778$).

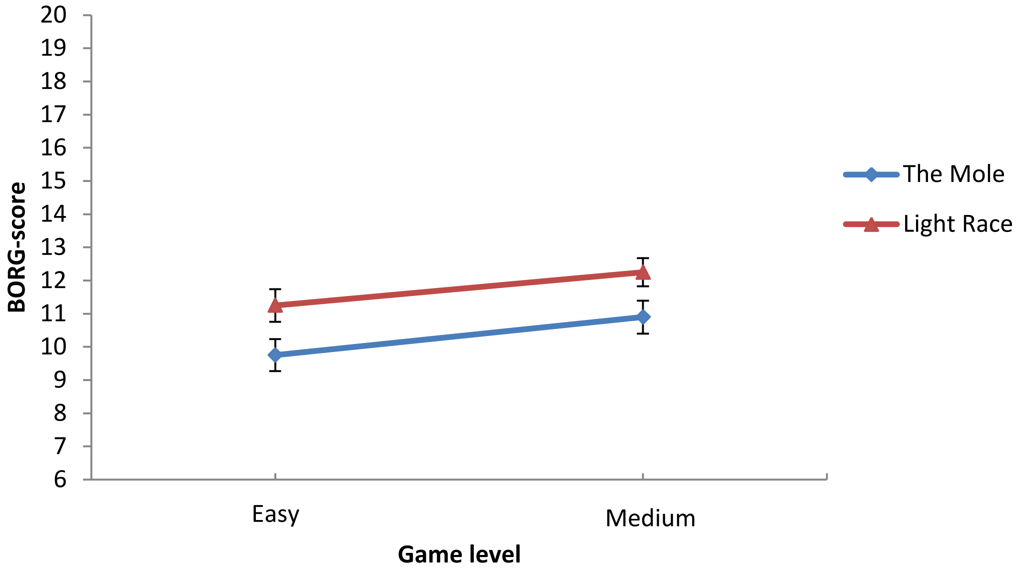

Figure 6. BORG-scores (perceived exertion, with SE error bars) in both exergames and both levels; 6= no exertion, 20= maximal exertion.

Furthermore, independent samples t-test showed that playing The Mole as the first game yielded a significantly lower BORG-score on The Mole easy level (8.60 ± 2.27) than playing LightRace as the first game (10.90 ± 1.28), $t(18)=-2.787$, $p=0.012$.

System usability and enjoyment

Both exergames were given above average scores on the System Usability Scale (SUS). The Mole had a slightly higher average SUS-score (80.69 ± 15.2) than LightRace, that had an average SUS-score of 75.83 ± 19.19. Paired-samples t-test indicated no significant difference between total SUS-score for The Mole and LightRace ($p=.323$). Independent samples t-tests indicated that system usability was not significantly affected by what game the participants played first (p=.485 for The Mole, p=.843 for LightRace) or by gender (p=.482 for The Mole, p=.421 for LightRace).

The interview questions revealed a high level of enjoyment of the exergames in general, and none were afraid to fall when playing. An important note is that when participants were asked about the exergames, their answers and attitudes towards the exergames reflected that they were not familiar with this kind of activity. Often the responses were not decidedly positive or negative, and the interviewer had to ask follow-up questions to clarify the participants' first response. The women were in general more positive than the men, who tended to have a slight ambivalence towards gaming by giving responses like "I guess" and "maybe". The men also saw a competitive side to it; playing to beat their own or a friends' score was in itself a motivation to accomplishing the exergames.

After participants had played The Mole, the participants reported to find it enjoyable. It was fun and easy to play, and the idea of being in physical activity while "playing" was appealing. Also, the cognitive challenge was mostly positive; having to focus and concentrate to achieve high scores, especially at the medium level, was seen as a fun obstacle rather than an overwhelming task. However, some reported the ladybugs to be very challenging, and some even chose to ignore them and focus solely on hitting the positive targets (moles and mice). There was general consensus that the medium level was favored over the easy level because of the more challenging cognitive elements. Regarding the question whether the participants would like to use The Mole as a form of physical activity, most answered that they would consider it, or that it would be more relevant later in life, or even just as an activity to engage in with grandchildren.

After playing LightRace, participants also gave positive feedback. In general, the game was said to be fun to play, and it was more physically than mentally challenging even though most said the game required focus and attention. The fact that the avatar on the screen was a mirror image of the player posed an additional challenge for many, as the avatar on the screen moved towards the participant when he/she stepped forward and away when the player stepped backwards. This seemed illogical to many of the players, especially those who had played The Mole first, and often resulted in steps that were initially in the wrong direction. This became less of a problem at the medium level, as it allowed for steps backwards and participants became more used to it by completing more trials. This seemed to play a role in making the participants like the medium level better than the easy level, and the slightly more challenging cognitive task in the medium level was also seen as positive. Participants answered similarly as regarding The Mole on the question whether they would like to use LightRace as a form of physical activity; if it proved to be positive for balance most would consider using it either now or later.

Movement sizes and area coverage

The amount of movement of toe and lumbar markers was quantified as the IQR in each horizontal movement direction separately (A-P and M-L) and in both directions combined as a 2D area.

Results on toe and lumbal interquartile range (IQR), as seen in Figure 7, showed that in the anterior-posterior direction, toe IQR was 29.37 ± 13.9 cm in the Mole easy, 25.76 ± 15.46 cm in The Mole medium; 30.40 ± 14.44 cm in LightRace easy and 29.18 ± 11.28 cm in LightRace medium. In the same A-P direction, lumbar IQR was 26.48 ± 12.77 cm in The Mole easy; 22.48 ± 14.08 cm in The Mole medium; 27.59 ± 12.62 cm in LightRace easy and 26.15 ± 10.53 cm in LightRace medium. A Three-Way repeated measures ANOVA Game (2) by Level (2) by BodyPart (2) indicated a significant main effect of Level, $F(1,18)=8.632$, $p=.009$, and BodyPart, $F(1,18)= 42.777$, $p<.0005$. No significant interactions were found, with all p's>.600.

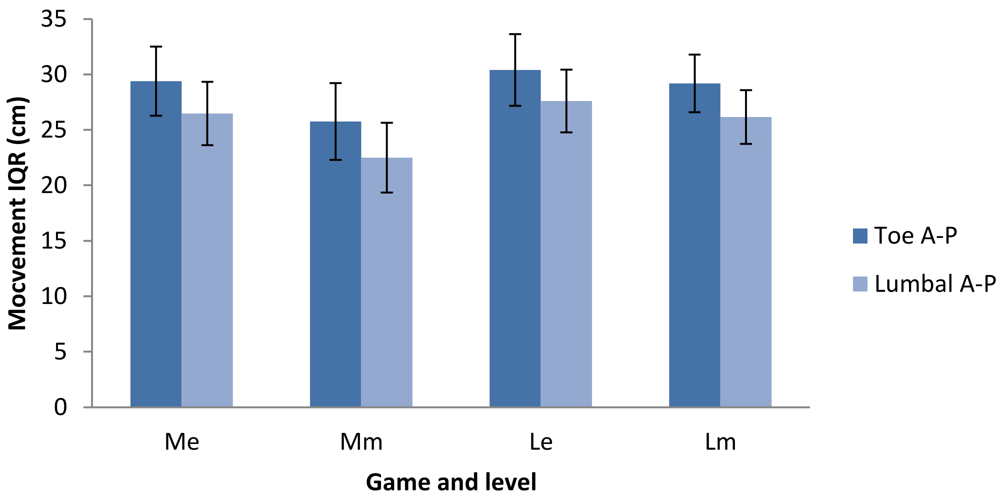

Figure 7. Average IQR (cm, with SE error bars) for toe and lumbar marker in the anterior-posterior (A-P) direction for TheMole easy (Me), The Mole medium (Mm), LightRace easy (Le) and LightRace medium (Lm).

In the medio-lateral (M-L) direction, illustrated in Figure 8, the toe IQR was 27.47 ± 14.12 cm in The Mole easy, 24.64 ± 11.47 cm in The Mole medium; 26.55 ± 13.32 cm in LightRace easy and 28.17 ± 13.39 cm in LightRace medium. The lumbar IQR was 19.34 ± 15.11 cm in The Mole easy, 17.34 ± 13.50 cm in The Mole medium; 19.41 ± 13.81 cm in LightRace easy and 18.70 ± 12.79 cm in LightRace medium.

A Three-Way repeated measures ANOVA Game (2) by Level (2) by BodyPart (2) confirmed a significant main effect of BodyPart, $F(1,18)=49.882$, $p<.0005$, and a significant interaction between Game, Level and BodyPart, $F(1,18)=5.800$, $p=.027$. As can be seen in the figure, this interaction was likely caused by all IQR decreasing from easy to medium level except for the toe in LightRace.

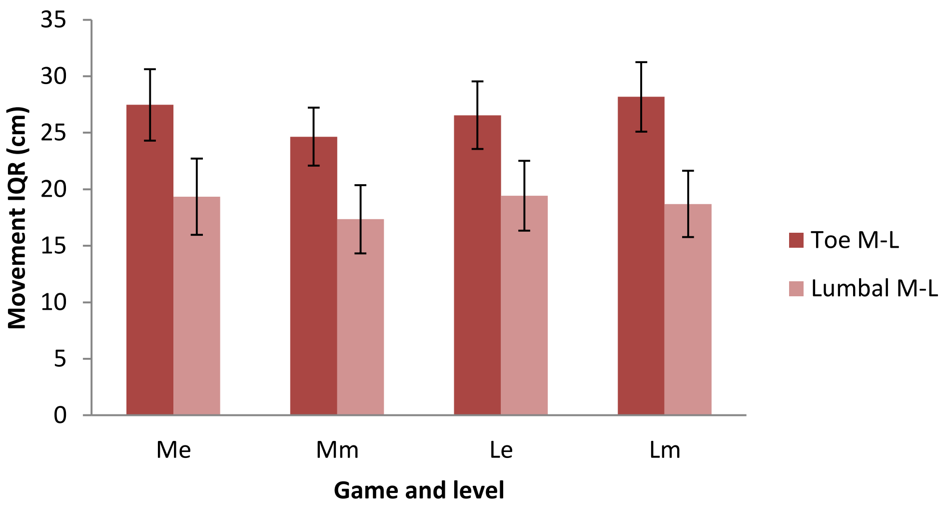

Figure 8. Average IQR (cm, with SE error bars) for toe and lumbar marker in the medio-lateral (M-L) direction for TheMole easy (Me), The Mole medium (Mm), LightRace easy (Le) and LightRace medium (Lm).

The IQR of vertical movements of the lumbar marker, shown in Figure 9, were on average 4.36 ± 2.19 cm in The Mole easy, 3.95 ± 1.63 cm in The Mole Medium, 4.26 ± 2.00 cm in LightRace easy and 3.93 ± 2.01 cm in LightRace medium. Two-Way repeated measures ANOVA on Game (2) by Level (2) indicated no main effects of Game ($p=.688$) or Level ($p=.153$) on vertical movement of the lumbar marker, and no significant interaction between Game and Level ($p=.710$).

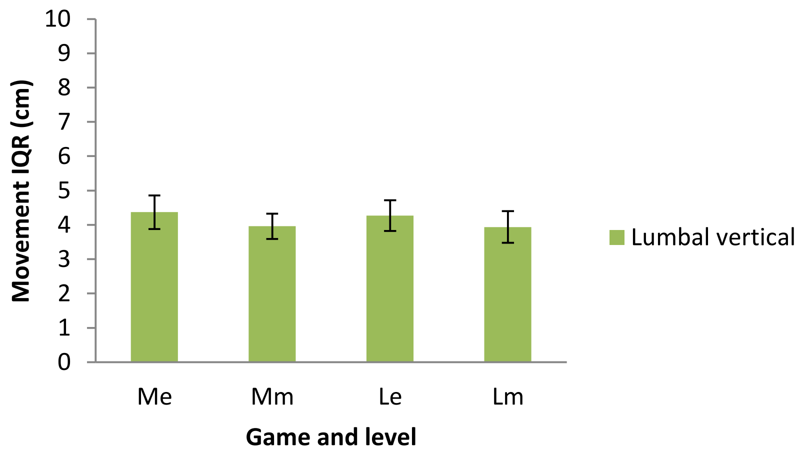

Figure 9. Average IQR (cm) for lumbar marker in the vertical direction for TheMole easy (Me), The Mole medium (Mm), LightRace easy (Le) and LightRace medium (Lm).

Analyses of movement sizes of the lumbar area and toe area (Figure 10) showed that the toe marker covered on average an area of 10,839.50 ± 3,431.07 cm^2 in The Mole easy, 9,624.58 ± 3,333.42 cm^2 in The Mole medium; 12,315.98 ± 3,735.31 cm^2 in LightRace easy and 11,171.15 ± 2,631.43 cm^2 in LightRace medium. The lumbar marker covered on average an area of 5,037.73 ± 4,751.91 cm^2 in The Mole easy, 4,278.44 ± 4,390.52 cm^2 in The Mole medium, 5,658.97 ± 4,352.45 cm^2 in LightRace easy and 5,017.68 ± 3,983.00 cm^2 in LightRace medium. Three-Way repeated measures ANOVA Game (2) by Level (2) by BodyPart (2) showed a significant main effect of Level, $F(1,18)=11.460$, $p=.003$, and BodyPart, $F(1,18)=230.038$, $p<.0005$. No significant interactions were found, with all p's>.175.

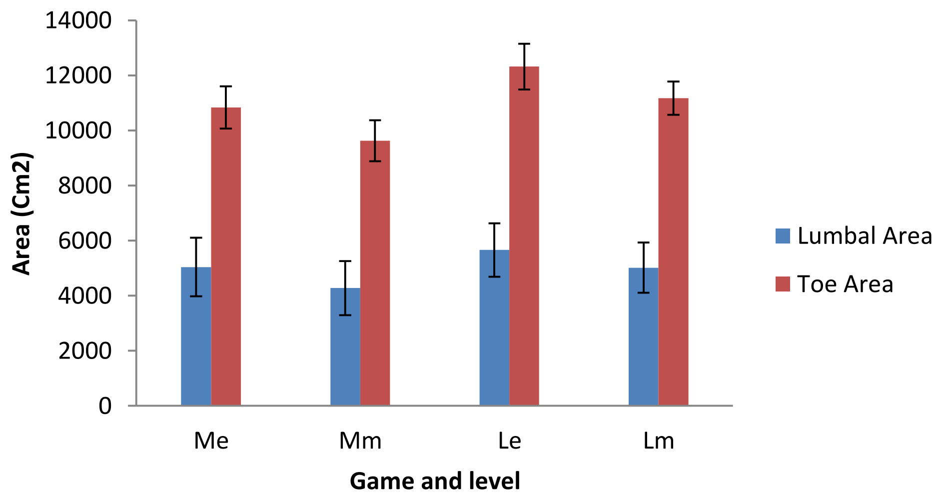

Figure 10. Mean toe and marker lumbar area (cm^2, with SE error bars) for TheMole easy (Me), The Mole medium (Mm), LightRace easy (Le) and LightRace medium (Lm).

Relationships between variables

We also tested for possible relationships between the different variables reported above. Correlational analyses of game scores and BORG-scores indicated medium to strong negative correlations in LightRace easy (Spearman's ρ = -.592, p=.006) and medium (Spearman's ρ = -.816, p=.000) levels (Table 3). In The Mole, this was not found (p=.915 and p=.575 for easy and medium level, respectively). Furthermore, Table 3 shows a medium correlation between game scores and SUS-scores at the medium level for both exergames (Spearman's ρ=.482, p=.037 for The Mole medium and ρ=.620, p=.005 for LightRace medium). These correlations were not significant at the easy level for neither of the exergames (p=.488 for The Mole easy and p=.066 for LightRace easy). Game scores were not significantly correlated with toe or lumbar area, or toe or lumbar range (IQR) in either A-P, M-L or vertical directions (Table 3).

Between BORG and SUS-scores, there were significant negative correlations (see Table 3) at the medium level for both exergames (Spearman's ρ = -.485, p=.035 for The Mole medium, and ρ = -.548, p=.012 for LightRace Medium), but this was not found at the easy levels (p= .330 for The Mole, p= .215 for LightRace). BORG scores were not significantly correlated with toe or lumbar area, or toe or lumbar range (IQR) in either A-P, M-L, or vertical directions. This was also the case for SUS-scores, as can be seen in Table 3.

Table 3. Spearman's Rho and Pearson's correlation coefficients with associated p-values between game scores, BORG-scores, SUS-scores, toe range (cm) in A-P and M-L directions, lumbar range (cm) in A-P, M-L, and vertical directions, toe area (cm^2), and lumbar area (cm^2).

	GAME SCORES				**BORG**				**SUS**			
	The Mole		**LightRace**		**The Mole**		**LightRace**		**The Mole**		**LightRace**	
	Easy	**Medium**	**Easy**	**Medium**	**Easy**	**Medium**	**Easy**	**Medium**	**Easy**	**Medium**	**Easy**	**Medium**
	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ
	(p-value)	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*
BORG	.025	.169	**-.592**	**-.816**	-	-	-	-	-	-	-	-
	(.915)	*(.478)*	***(.006)***	***(.000)***								
SUS	.169	**.482**	.418	**.602**	-.236.	**-.485**	-.290	**-.548**	-	-	-	-
	(.488)	***(.037)***	*(.066)*	***(.005)***	*(.330)*	***(.035)***	*(.215)*	***(.012)***				
Toe Range M-L	-.169*	.035*	.117*	-.022*	-.246	.145	-.169	-.033	-.142	-.088	.130	-.004
	(.477)	*(.885)*	*(.454)*	*(.930)*	*(.297)*	*(.542)*	*).475)*	*(.893)*	*(.561)*	*(.720)*	*(.586)*	*(.989)*
Toe Range A-P	-.363*	-.099*	.203*	.098*	-.318	.100	-.371	-.076	-.012	-.059	.078	.137
	(.116)	*(.678)*	*(.390)*	*(.689)*	*(.172)*	*(.675)*	*(.108)*	*(.757)*	*(.960)*	*(.811)*	*(.745)*	*(.575)*
Lumbar Range	-.282*	-.004*	.198*	.084*	-.213	.115	-.331	-.034	-.069	.004	.093	-.004
M-L	*(.229)*	*(.987)*	*(.404)*	*(.732)*	*(.367)*	*(.628)*	*(.154)*	*(.890)*	*(.780)*	*(.989)*	*(.695)*	*(.986)*
Lumbar Range	-.344*	.130*	.177*	.092*	-.276	.112	-.425	-.068	-.018	-.054	.002	.013
A-P	*(.137)*	*(.586)*	*(.456)*	*(.709)*	*(.238)*	*(.638)*	*(.061)*	*(.783)*	*(.943)*	*(.827)*	*(.995)*	*(.957)*
Lumbar Range	.407*	.003*	.080*	.253	.374	-.277	.101	-.044	.274	.351	.003	.286
Vertical	*(.075)*	*(.991)*	*(.739)*	(.296)	*(.104)*	*(.237)*	*(.673)*	*(.858)*	*(.256)*	*(.141)*	*(.990)*	*(.235)*
Toe Area	-.065*	.042*	.240*	.304*	-.191	.076	-.464	-.107	.129	.082	.158	.082
	(.785)	*(.862)*	*(.308)*	*(.206)*	*(.420)*	*(.749)*	*(.390)*	*(.662)*	*(.598)*	*(.739)*	*(.505)*	*(.739)*
Lumbar Area	-.277*	-.058*	.171*	.236*	-.186	.198	-.382	-.049	.006	-.074	.114	-.050
	(.237)	*(.807)*	*(.470)*	*(.330)*	*(.432)*	*(.402)*	*(.097)*	*(.843)*	*(.980)*	*(.764)*	*(.633)*	*(.838)*

*Pearson's r correlation coefficien

Discussion

The aim of this study was to investigate usability, enjoyment and movement characteristics when elderly were playing two different exergames. The participants in the study were a relatively healthy, active group of elderly, as indicated by high activity levels, about one hour each day. Furthermore, the results on background variables and physical function are outside the range of what has been shown to be associated with increased fall risk. Participants took on average less than 2 daily prescription medications, whereas risk of falling increases at 4 or more (S. Mizukami 2013) and they scored low on the Falls Efficacy Scale, below 20 on a scale from 16-64. Furthermore, they managed over 14 chair rises in 30 seconds, whereas less than 8 is associated with increased risk of falling (R.E. Rikli 1999). Finally, at an average of 1.36 m/s their walking speed is well above the 1.0 m/s that is considered to be associated with a high risk of major health-related events, including increased risk of falling (M. Cesari 2005, M. Montero-Odasso 2005).

User friendliness and enjoyment

The two exergames we used in this study, The Mole and LightRace, were both generally popular and user friendly, as the elderly reported in both interview questions and on the SUS-form. This is consistent with results found in previous studies (M. van Diest 2013). The positive attitude towards this kind of physical activity provides incentives to further develop exergames for elderly, as they report that they will likely engage in it in the future as well. However, this seemed to be on the premise that the exergames are designed in a way that makes the elderly feel sufficiently challenged both mentally and physically, at an appropriate level in relation to the physical form they are currently in. Participants generally preferred the medium levels over the easy levels; this seemed to be due to the more challenging cognitive tasks at the medium levels, as well as the reduction of the "mirrored avatar-problem" in LightRace medium. The participants reported that they felt that the more challenging cognitive task was more motivating and that they enjoyed the increased attention it demanded. Several also pointed out that they preferred it because this type of cognitive task was different from what they experienced on a daily basis, and that they wished to engage in similar activities more frequently to "keep the brain sharp". As previous research has shown, adding a cognitive element and thereby creating a dual task condition increases elderly's reaction time during a postural task (I. Melzer 2004), and that training this ability should therefore be implemented in balance training (P. Shilsupadol 2009, Pellecchia 2010).

The results on perceived exertion showed that the increased challenge at the medium level was physically more strenuous as well, but not to the extent that the participants felt that it was *too* strenuous as they still preferred it over the easy levels. However, this result seems inconsistent with the negative relationship between SUS-scores and perceived exertion, indicating that higher exertion was associated with lower scores on user friendliness. As the BORG-scale was marked before the SUS-form was filled in, marking a higher BORG-score may have affected the participants' impression of the game, thereby resulting in a lower SUS-score. However, from correlational analyses alone we cannot know whether higher perceived exertion made participants like the game less (lower SUS score), or vice versa.

Game scores also indicated that the medium levels were more difficult than the easy levels, as game scores decreased from easy to medium. For LightRace, this resulted in a negative relationship between perceived exertion and game scores. In addition, the larger differences in game scores between levels in The Mole compared to LightRace point to a larger difference in difficulty between the levels in The Mole. In this game, the medium level introduces challenging cognitive elements where the player must separate between positive targets (moles and mice) and negative targets (ladybugs). By having to avoid negative targets, not only attention to hitting positive targets may have been reduced but also the opportunity to do so. In LightRace, the increased cognitive challenge came in the form of an increase in number of possible positions of targets, and these continued to be all positive.

Interestingly, participants who played The Mole as the first game tended to achieve lower game scores in LightRace at both easy and medium level. Although this effect was not significant, it suggests that participants transfer playing habits learned from one game to the next. As The Mole has a larger gaming area and allows for a larger variety in movements, this may have resulted in a less efficient movement pattern in LightRace, as the players had to adapt their movements to new and stricter game settings. This trend was less visible when playing LightRace before The Mole, which might be because stepping movements in The Mole can be less strict while still successfully hitting targets, and therefore the previously learned movement patterns from

LightRace may be easier to adapt to The Mole. The indication that participants learned how to control the exergames in an increasingly efficient manner as they completed more trials was also reflected in increasing game scores as more trials were played. BORG and SUS-scores were not affected by what game was played first, perhaps because the exergames were scored so similarly by the participants.

Movement sizes and area coverage

Both in the A-P direction and in the M-L direction, the movement range of the feet was larger than the movement range of the trunk. This indicates that the participants moved their feet further out than they moved their trunk, and this difference tended to be largest in the M-L direction. The larger the difference between feet and trunk movements, the more the participants used tapping movements rather than weight transfer, suggesting that participants had more weight transfer in the A-P than the M-L direction. This is consistent with previous research showing that it is inherently more challenging to control sideways movement of one's body mass compared to moving it forward (MacKinnon and Winter 1993). However, as the ability to control weight transfer sideways is important in being able to prevent falls (Maki and McIlroy 2006, Hillard, Martinez et al. 2008), this needs to be included in physical activity that is aimed at fall prevention through stepping and balance training (Sherrington, Whitney et al. 2008).

The increased challenge at the medium levels in both exergames generally reduced the participants' range of movements of the trunk and feet in both horizontal directions. However, this was not the case in the M-L direction in LightRace where the movement range of the feet slightly increased from easy to medium level. In The Mole, this overall decrease in movement size from easy to medium is not surprising, as the participants had to be careful not to hit the ladybugs at the medium level, inducing them to be more careful and thereby reducing feet and trunk movements. It could also be due to the participants learning how to move in a more efficient manner and still score points, but the simultaneous decline in game score suggests that this is not a likely explanation.

In the vertical direction, the small movement ranges of the trunk indicated that participants moved their trunk slightly up and down when taking steps, which is likely caused by the knee and hip muscles countering the forces of the movement as seen during normal walking (Winter 1995).

Furthermore, the range of the vertical movement in the trunk did not change across exergames or levels, showing that the different exergames and levels used in this study did not have an effect on the amount of trunk movement in the vertical direction.

Regarding area covered during gameplay, the results are largely similar to the results on movement range. The feet covered an area about twice as large as the trunk covered in both exergames and at both levels. This indicates that the participants moved their feet around the gaming area more than they did their trunk, which again indicates more tapping than weight shift. Additionally, the results showed differences in area coverage in both the feet and the trunk between the levels in the exergames: the easy level elicited larger area coverage than the medium levels in both exergames, which again may be due to the more challenging task in the medium levels, inducing the participants to restrict their movements.

The relationship between game scores and movement variables is interesting because of the lack of a positive correlation between the movement variables and game scores in either of the exergames or levels. This may indicate that the exergames do not encourage the players to an adequate extent to move in the desired manner in order to achieve high game scores. As a negative correlation was also not found, this indicates that the exergames do not reward the players either for doing the wrong movements in relation to balance training, so-called cheating. For exergames to be most effective as a balance training intervention, exergames should be developed in such a way that appropriate movements are recognized and rewarded with points, and there should be added attention to weight shift in the medio-lateral direction. Similarly, attempts to cheat and achieve high scores without performing the appropriate movements should not be rewarded by scoring points.

Overall, the results showed that the movements elicited by the two exergames and responses to questions about enjoyment and usability of the two exergames were fairly similar. This indicates that two stepping exergames, even though they are designed with two different target groups in mind, elicit similar responses and experiences in the players. It seemed that the largest difference the elderly observed between the exergames was that The Mole seemed more like a game designed for fun, and LightRace as aimed more directly at physical activity, but this was a subjective perception that did not seem to affect how much they enjoyed the exergames or the system usability.

Strengths and limitations of the study

To be best of our knowledge, this is the first study to objectively quantify participants' movements while playing exergames. As most participants were novice exergamers, we could study their first meeting and experiences with exergames. This study could have benefited from a larger number of participants and thereby boosting statistical power. However, given the quasi-experimental nature of the study, we deemed the number of participants to be sufficient in this study. As this was not an intervention study or a longitudinal learning study, the participants took part in only one session each. Our findings may prove useful in further development of exergames for exercise in the context of fall prevention, as they provide insights into which movements these exergames may elicit from an objective point of view.

An important limitation in the study was that the OQUS cameras could not be placed directly behind the participants because of their interference with the exergames camera systems, leading to a less than optimal placement to capture the heel markers in particular. In addition, the SilverFit camera system required an even surface close behind the participants, preventing us to place the OQUS cameras further back and out of the gaming cameras' detection area. Consequently, the placement of the OQUS cameras were at the side of the participants, which resulted in interruptions in the detection of heel markers , causing the data from the heel markers to be excluded from the present study.

Finally, weight transfer was approximated in this study by trunk movements. Direct measures of COM movement using force platforms or other methods that directly measure the displacement of the COM would have been more direct and accurate. Although we attached inertial sensors to the lower trunk using a smart phone, these are also an approximation of COM. Force sensors under the shoes could help establish to what extent players are tapping their feet only versus weight transfer.

Further analyses and future research

Regarding further analyses of the current data, it would be interesting to see if there are differences between the participants themselves that played a role in how they moved when playing exergames. Could there be particular traits that characterize the players who performed the appropriate movements, or is this mostly decided by the game design? Furthermore, it would be interesting to further investigate the movement patterns and strategies of those participants who achieved higher scores and compare these to the movement patters and strategies of participants scoring lower. The next step would be to use this knowledge in the design of exergames aimed at eliciting specific movement patterns in order to achieve the best possible training results.

Similarly, investigating changes in movement variables and how these changes affects one another would also be interesting, as this could give an additional indication about how to design exergames in order to efficiently elicit desired movements. This is essential if exergaming is to be used as a tool in fall preventive exercises, as clinicians and physical therapists need to be able to trust that the exergames efficiently utilize the correct movements required in this type of exercise. Regarding future research, an intervention study using exergames based on knowledge about the movements elicited would be very interesting with regard to the efficiency of exergames in fall prevention programs. The ultimate challenge is to develop a golden standard for elements needs in exergames to make sure that they successfully target fall preventive exercises.

Conclusion

The elderly in this study enjoyed playing the two exergames, Mole and LightRace, and higher difficulty levels did not seem to decrease the enjoyment of playing; in fact, the additional challenges were perceived as entertaining and enjoyable, without being very strenuous. Despite being very different exergames, both exergames elicited similar movements with respect to the size of steps and of trunk displacement. In eliciting movements that are desirable in balance training and fall preventive exercise, these two exergames are promising *steps* in the right direction, but they can be further improved with regard to rewarding desired movements and to disregard cheating movements.

It seems that exergames would benefit from combining a cognitive challenging task that is fun and motivating, with a more basic task that elicits the desired movements. This also needs to be rewarded with appropriate game scores in order to keep the players motivated, to give them a sense of accomplishment while playing, and to ensure that they continue to play using appropriate movements. The present study illustrates of the need to investigate the movements elicited and the subjective acceptance of exergames as physical activity among elderly, in order to provide an applicable exergame in the context of fall preventive exercise.

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Appendices

Appendix I – BORG scale

Når du spiller, bruk skalaen og din erfaring til å rapportere hvor hardt det har vært. Mens arbeidet pågår vil vi at du vurderer følelsen av anstrengelse, hvor tungt og anstrengende det er og hvor sliten du føler deg. Opplevelsen av anstrengelse arter seg hovedsakelig som tretthet i musklene og som andpustenhet eller eventuell verking i brystet. Forsøk å være så oppriktig og spontan som mulig, og tenk ikke så nøye over hva belastningen egentlig er. Forsøk verken å undervurdere eller overvurdere. Det viktige er din egen følelse av anstrengelse og ikke hva du tror andre mener. Se på skalaen og ta utgangspunkt i ordene, men velg så et tall og sett ring rundt det du mener passer best.

Bruk denne skalaen som går fra 6, «Ingen anstrengelse», til 20, «Maksimal anstrengelse». Her er en utdypende forklaring til uttrykkene bak noen av tallene i skalaen. Når du rapporterer – velg hvilke tall du vil på skalaen, ikke bare de rett foran uttrykkene.

6 «Ingen anstrengelse», betyr at du ikke merker noen anstrengelse i det hele tatt, for eksempel ingen muskeltretthet, ingen andpustenhet eller pusteplager.

9 «Meget lett». Som å gå en kort tur i sitt eget tempo.

13 «Litt anstrengende». Du kan fortsette uten større problemer.

15 Det er «anstrengende» og tungt. Du er sliten, men kan likevel fortsette.

17 «Meget anstrengende». En veldig stor påkjenning. Du kan fortsette, men må ta i veldig hardt og føler deg svært sliten.

19 «Svært anstrengende». For de fleste mennesker tilsvarer dette den aller største anstrengelsen de noensinne har opplevd.

«Ingen anstrengelse»

«Meget lett».

«Ganske lett»

«Litt anstrengende».

Det er «anstrengende» og tungt.

«Meget anstrengende».

«Svært anstrengende».

Appendix II – Interview Questions

Intervju-spørsmål:

Spill 1 – Easy: …….

- Var det artig spill?
- Kunne du brukt dette spillet for å holde deg fysisk aktiv i hverdagen?
- Var du redd for å falle mens du spilte?

Spill 1 – Medium: ……..

- Var det artig spill?
- Kunne du brukt dette spillet for å holde deg fysisk aktiv i hverdagen?
- Var du redd for å falle mens du spilte?
- Hva synes du om de to ulike nivåene? Hva var best/verst, evt om nr 2 var vanskelig?

Spill 2 – Easy: ……..

- Var det artig spill?
- Kunne du brukt dette spillet for å holde deg fysisk aktiv i hverdagen?
- Var du redd for å falle mens du spilte?

Spill 2 – Medium: ……..

- Var det artig spill?
- Kunne du brukt dette spillet for å holde deg fysisk aktiv i hverdagen?
- Var du redd for å falle mens du spilte?
- Hva synes du om de to ulike nivåene? Hva var best/verst, evt om nr 2 var vanskelig?

Appendix III – SUS-form

Noen spørsmål om systemet du har brukt.

Vennligst sett kryss i kun en rute pr. spørsmål.

	Sterkt uenig				Sterkt enig
1. Jeg kunne tenke meg å bruke dette systemet ofte.	1	2	3	4	5
2. Jeg synes systemet var unødvendig komplisert.	1	2	3	4	5
3. Jeg synes systemet var lett å bruke.	1	2	3	4	5
4. Jeg tror jeg vil måtte trenge hjelp fra en person med teknisk kunnskap for å kunne bruke dette systemet.	1	2	3	4	5
5. Jeg syntes at de forskjellige delene av systemet hang godt sammen.	1	2	3	4	5
6. Jeg syntes det var for mye inkonsistens i systemet. (Det virket "ulogisk")	1	2	3	4	5
7. Jeg vil anta at folk flest kan lære seg dette systemet veldig raskt.	1	2	3	4	5
8. Jeg synes systemet var veldig vanskelig å bruke	1	2	3	4	5
9. Jeg følte meg sikker da jeg brukte systemet.	1	2	3	4	5
10. Jeg trenger å lære meg mye før jeg kan komme i gang med å bruke dette systemet på egen hånd.	1	2	3	4	5

I

SUS
Norsk versjon ved Dag Svanæs
NTNU 2006

Appendix IV – FES-I Questionnaire

FES-I

De følgende spørsmålene handler om hvor bekymret du er for at du kan komme til å falle. Vi ber deg om å svare ut fra hvordan du vanligvis utfører aktiviteten. Hvis du for tiden ikke utfører aktiviteten (for eksempel hvis noen andre går i butikken og handler for deg), vil vi be deg angi om du tror at du ville være bekymret for å falle HVIS du utførte aktiviteten. Kryss av for utsagnet som ligger nærmest opp til din egen opplevelse av, i hvor stor grad du er bekymret for å falle.

		Ikke bekymret i det hele tatt *1*	*Litt bekymret* *2*	*Ganske bekymret* *3*	*Veldig bekymret* *4*
1	Gjøre rent i huset (f.eks. tørke støv, støvsuge eller vaske)	*1* ☐	*2* ☐	*3* ☐	*4* ☐
2	Kle av eller på deg	*1* ☐	*2* ☐	*3* ☐	*4* ☐
3	Tilberede enkle måltider	*1* ☐	*2* ☐	*3* ☐	*4* ☐
4	Bade eller dusje	*1* ☐	*2* ☐	*3* ☐	*4* ☐
5	Gå i butikken	*1* ☐	*2* ☐	*3* ☐	*4* ☐
6	Reise deg opp fra, eller sette deg ned på en stol	*1* ☐	*2* ☐	*3* ☐	*4* ☐
7	Gå opp eller ned trapper	*1* ☐	*2* ☐	*3* ☐	*4* ☐
8	Spasere i nabolaget	*1* ☐	*2* ☐	*3* ☐	*4* ☐
9	Strekke deg for å nå ting over hodehøyde eller bøye deg for å ta opp ting fra golvet	*1* ☐	*2* ☐	*3* ☐	*4* ☐
10	Ta telefonen før den stopper å ringe	*1* ☐	*2* ☐	*3* ☐	*4* ☐
11	Gå på et glatt underlag (f.eks. vått eller isete)	*1* ☐	*2* ☐	*3* ☐	*4* ☐
12	Besøke en venn eller slektning	*1* ☐	*2* ☐	*3* ☐	*4* ☐
13	Gå på sted der det er mange mennesker	*1* ☐	*2* ☐	*3* ☐	*4* ☐
14	Gå på ujevnt underlag (f.eks. dårlig vedlikeholdt fortau, grusvei)	*1* ☐	*2* ☐	*3* ☐	*4* ☐
15	Gå opp eller ned en skråning	*1* ☐	*2* ☐	*3* ☐	*4* ☐
16	Delta i sosiale sammenkomster (f.eks. gudstjeneste, familiesammenkomst, møte)	*1* ☐	*2* ☐	*3* ☐	*4* ☐

FES-I Norwegian translated from English by Dr Jorunn L. Helbostad

Appendix V – Background information

Bakgrunnsinformasjon

På følgende spørsmål ønsker vi at du svarer så presist og ærlig som mulig. Hvis du ikke finner et svaralternativ som passer nøyaktig for deg, vil vi at du gir det svaret som er nærmest din virkelige verdi.

Deltaker nummer:

Fødselsår:

Kjønn (ring rundt): KVINNE MANN

Høyde (måles): cm

Vekt (måles): kg

Har du gått av med pensjon

JA NEI

Har du prøvd lignende spill tidligere? JA NEI

Hvis ja, vennligst angi hvilke(n) type(r):

1. Trening (f.eks. Zumba, balansetrening, gå-trening, reaksjonsspill)

2. Fornøyelse (f.eks. Super Mario, bilspill, fotballspill)

3. Mental trening (f.eks. Sjakk, hukommelsesspill, oppgaveløsning)

4. Annet (vennligst noter) ________________________________

Har du opplevd å falle uten særlig grunn i løpet av de siste 3 månedene (ring rundt)?

JA NEI

Hvis ja, ute eller inne?

Ute

Inne

Begge

Hvor mange medisiner tar du til daglig?

Antall:

Fysisk aktivitet på fritiden (i løpet av en gjennomsnittlig uke). Dette gjelder alt av aktiviteter der du er i bevegelse som får opp pulsen. Eksempler kan være å gå tur, løping, løfting, snømåking, gressklipping, og alle former for fysisk trening).

Hvor ofte (kryss av)?

O: Mindre enn 1 gang i uka

1: 1-2 ganger i uka

2: 2-3 ganger i uka

3: 3-4 ganger i uka

4: 4-5 ganger i uka

5: 5-6 ganger i uka

6 : 6 eller flere ganger i uka

Hvor anstrengende er aktiviteten?

1: Veldig lett

2. Litt anstrengende

3. Ganske anstrengende

4. Veldig anstrengende

Hvor lenge varer aktiviteten gjennomsnittlig?

1: 0-30 min

2: 31-60 min

3: 61-90 min

4: 91-180 min

5: 181 min +