A Balance Training Game Tool for Seniors using Microsoft Kinect and 3D Worlds

Michail Chartomatsidis and Christos Goumopoulos
Information and Communication Systems Engineering Department, University of the Aegean, Greece

Keywords: Exergaming, Seniors, Microsoft Kinect, Motion-based Exercise Game, Berg Balance Scale, Human Centered Design, Ambient Assisted Living.

Abstract: Exercising through gaming (exergaming) based on commercial gaming platforms has been popular over the past years for fitness improving and balance training both for healthy people and for mobility rehabilitation purposes. For the elderly people, exergaming can provide motivation for increasing physical and cognitive activity and as a result improvements on posture balance, physical strength and mental well-being may be expected. However, an issue that arises is whether such gaming systems that are addressed to the general population following a fit-for-all design approach are appropriate for seniors. In this paper we address this issue by developing a new game based on the Microsoft Kinect sensor and creating an engaging three-dimensional world by using a popular 3D game engine. A human centered design approach is followed by involving main stakeholders in the development process for achieving an effective and user-friendly balance training. An evaluation of the proposed game tool with twelve seniors has been performed assessing system usability as well as the balance training efficacy measured by the Berg Balance Scale and the 30 seconds sit-to-stand test. The analysis of the feedback provided by the users and the performance statistics exported by the system indicates a positive acceptance and the potential for promoting health in older adults through balance improvement.

1 INTRODUCTION

Exercise games (known as exergames) appear to be a promising approach for home-based balance and strength training for healthy elderly (Lamoth et al., 2011). Exercising through games can encourage people to train and by performing game scenario tasks they can train both mental and physical skills. In this direction, there is positive evidence that exercise programs that combine balance training and muscle strengthening and coordination can reduce falls and fall risk in the elderly (Sherrington et al., 2011).

During the past years off-the-self gaming consoles like Microsoft Kinect XBOX 360, Sony Playstation Eyetoy and Nintendo Wii have been pervasive. Such systems have introduced a new style of physical interaction based on gestures and full body motions and have been used for training balance and improving fitness for healthy elderly (Van Diest et al., 2013) as well as for medical purposes as rehabilitation tools (Goble et al., 2014).

However, the issue that arises is whether such gaming systems that are addressed to the general population following a fit-for-all design approach are appropriate for seniors. Usability studies with the participation of seniors have found that popular commercially available games are not necessarily suitable for seniors due to their complex interface and game structure (Gerling and Masuch, 2011). Negative feedback when the players frequently fail to perform game tasks because their movements are slower than expected by the game have been also reported (Lange et. al, 2009). Many exergames are inappropriate for balance trainning because they are not properly designed for controlled movements of seniors body centre of gravity (Sugarman et al., 2009) and their use can cause injuries (Bateni, 2012). Furthermore, commercial gaming platforms are not flexible enough to provide exergame personalization taking into account the specific needs of an individual and their cost is considerable.

In this paper we present the design and development of a game tool that combines Microsoft Kinect technology to capture body movements, Unity graphics engine to create a 3D world for game scenes, a software module to manage game logistics and

Chartomatsidis, M. and Goumopoulos, C.
A Balance Training Game Tool for Seniors using Microsoft Kinect and 3D Worlds.
DOI: 10.5220/0007759001350145
In *Proceedings of the 5th International Conference on Information and Communication Technologies for Ageing Well and e-Health (ICT4AWE 2019)*, pages 135-145
ISBN: 978-989-758-368-1

special tailored games for active balance training of seniors. Following a human centered design aproach and a set of proper design guidelines that take into account the special needs of seniors the aim was to provide a gaming tool that is both enjoyable to use and has a practical impact on improving seniors balance. To assess the usefulness of the tool a pilot study has been performed with the participation of 12 seniors for a period of five weeks using evaluation metrics such as the Berg Balance Score (BBS), the 30 seconds sit-to-stand test and a questionaire for assessing usability factors. The qualitative and quantitative analysis of the pilot data shows that this tool can be used to assist seniors in improving their balance in an enjoyable and engaging manner.

The rest of the paper is organized as follows. Section 2 presents related work. Sections 3 and 4 discuss the game design process and the details of system development, respectively. Section 5 discusses game tool evaluation in terms of assessing system usability and the balance training efficacy. Finally, our conclusions and suggestions for future work are given.

2 RELATED WORK

The development of special purpose computer games to assist the elderly, mostly for memory training, can be traced back in the 1980s (Weisman, 1983). When the motion tracking sensors were introduced a new wave of research was initiated. Exergames in the field of Ambient Assisted Living (AAL) have been targeted to enable the elderly to remain physically and mentally fit through engaging game activities as well as for rehabilitation purposes through specially designed balance exercises (Korn et al., 2013).

Several studies have explored the appropriateness of commercial game consoles for balance training of seniors (Van Diest et al., 2013). In particular the suitability of Microsoft Kinect sensor on enhancing physical exercising and performing rehabilitation protocols has been explored by Mousavi Hondori and Khademi (2014). Their review indicates that Kinect is an adequate device for balance exercising and monitoring of the elderly.

A training intervention program was performed in a quadruplet of care centers in Australia based on the Wii Fit bowling game played in Nintendo Wii (Chesler et al., 2015). Seniors were invited to play the game twice a week for six weeks with the support of a caregiver. The study indicated that exergaming can have a positive impact both on physical and psychological well-being assessed through relevant scales. The training program provided opportunities for social interactions between the participants when the game was played in groups affecting positively the sense of belonging.

Although the use of commercially available games is promising for the balance training of seniors there is a strong evidence that the development of specially designed games in a process involving all major stakeholders (i.e. elderly, caregivers, physiotherapists and developers) can serve more efficiently exercising intervention goals (Brox et al., 2017).

A research study performed with elderly in Japan designed and evaluated four exergames developed on the Microsoft Kinect platform with a goal to improve seniors' strength, balance and mobility (Sato et. al., 2015). The games entailed movements such as grabbing virtual objects using both arms, placing the feet along a straight line, bending knees and hips, crouching and standing on one leg. The users had to perform movements in the context of a game scenario while tasks were becoming more complicated based on the game's level of difficulty. The intervention brought an improvement in daily walking movements as measured by the Berg Balance Scale.

Similar exergames in an AAL environment were examined by Brauner and Ziefle (2015). Their study focused on assessing factors affecting user performance and technology acceptance. Various factors were explored such as technology skills, accomplishment orientation, playing frequency, age and gender. The principal factor for performance prediction was determined to be the participants' age, whereas for technology acceptance, in terms of intention to use such exergames, was the playing frequency. Playing frequency was defined based on the frequency the elderly would play games (e.g., cards, board games, bowling, etc.) in their daily life.

The proposed approach in this paper shares similar goals with the related work and embraces the perspective of developing tailored exergames based on a human centered design approach to identify requirements that are closer to the motor and cognitive abilities of seniors. On the sensor technology side instead of the XBOX 360 device the newer XBOX One Kinect device is employed. Besides providing higher resolution more skeleton joints can be tracked (e.g., thumb joints and hand tip) which allows for identifying more movement combinations. On the game side, further to the basic movements that were used in previous studies, the ability for the user to walk is provided. Moreover, a three-dimensional world was created using Unity 3D game engine embellished with narrative features through animations, sound and visuals for achieving a more realistic game experience. Although the game requires the use of the Kinect sensor to identify user's movements, there is no dependency on the corresponding game console, thus keeping the cost of the necessary hardware low.

3 HUMAN CENTERED DESIGN

The proposed game tool development was based on the human centered design (HCD) approach (Wever et al., 2008). Under the HCD principles the game design followed an iterative process starting with main stakeholders meetings and user focus groups to identify possible interaction activities and basic game mechanisms pertinent to the intervention goals of the game. Face-to-face meetings between game designers, seniors, medical professionals and caregivers allowed for acquiring both qualitative data through brainstorming activities and quantitative data through usability questionnaires to refine the main game characteristics and define the body movements that will be trained throughout the game.

After the initial design was formed a rapid prototyping of game ideas and mechanisms was delivered that was evaluated by the users. User feedback on the design and game concepts was analyzed by the development team to determine prototype appropriateness. A redesign cycle was followed with refined game rules and interactions before the final prototype development commenced.

The involvement of seniors under HCD guidelines from game requirements analysis and design to evaluation was essential in order to adequately capture their preferences and needs. The iterative user feedback expected to deliver a game tool that will be both useful in terms of balance training and enjoyable in terms of playing experience.

3.1 Design Guidelines

A number of design guidelines for exergames have been gathered from reviewing related research (Gerling et al., 2012; Planinc et al., 2013) and feedback by the elderly people in the HCD process.

Physiological constraints: The design of the game must take into account the target audience physical capabilities. Ageing will often lead to both cognitive and physical negative changes, like decline in memory, balance and physical strength. In that sense, the game structure must avoid unsuitable movements that may cause injuries and should allow longer reaction times. Also, it would be easier for the seniors to deal with only a single task each time.

Game theme. The theme of the exercise game should be related to real-life activities that are familiar to elderly people. Themes that are associated to natural life such as walking in a forest, picking apples and fishing are more acceptable than artificial settings found in commercial video games.

User interface. To concentrate on the actual exercise the user interface should be simple and easy to use. All instructions have to be clear and use common language. The interface should have different alternatives for multimedia presentation, such as, text, voice and images. For those who are visually impaired, for example, an audio presentation might be preferable.

Provide Instructions: Learning the game movements before starting the actual game should be provided as a choice to the users. Once those instructions are not required any more, users should have the option to avoid them. Furthermore, it should not be expected that the user will recall the instructions, so every time the user wants to start the game an option to view the instructions should appear.

Avoid small objects: It is easier for the elderly to identify large objects rather than small or fast moving.

Positive feedback: Motivating feedback should be given to encourage play. Constructive feedback should be given to guide and correct exercises. Information and feedback should be given when appropriate, to not disturb the user.

Variety of difficulty levels: For users to keep their motivation and continue playing, exergames should include different levels of difficulty. With that users will be able to test their skills and try to become better. Also moving to a more difficult level will make users feel that they accomplished something good and the game in fact helps them.

User profile: There should be made a profile where the user's progress and results can be saved.

3.2 Game Concept

Based on the guidelines mentioned in the previous section a game called "Fruit Collector" was conceptualized. The main purpose of the exergame is to pick up objects that are scattered around the environment and deliver them to appropriate spots.

The movements involved in the game design target improvements in balance and walking abilities. Furthermore other cognitive properties could benefit such as memory, attention and synchronization.

Since the exergaming is based on Microsoft Kinect sensor, the game entailed the design of gestures and body movements to interact with the game's environment. During the HCD process and interviewing with seniors and domain experts (orthopedics and physiotherapists) the decision was to include four activities. Specifically, leaning left and right to rotate to the corresponding direction, on site walking to move forward and the hand gestures open and closed to pick up and drop objects.

It is worth mentioning that in the first game design cycle there were movements like bending knees and hips and head leaning but after playtesting these movements with seniors and given the experts' feedback these movements were removed as they could be unsafe for some seniors.

During game design the feedback of the user focus group indicated a topic close to the seniors' interests. Thus, the idea was to create a forest with trees and flowers while in the centre of it a small village was placed. As for the collected/scattered objects the decision was to be baskets filled with fruits of different type. Finally, the brainstorming indicated that the places to deliver these baskets should be the houses of the village.

Moreover, different levels of difficulty were added to the game. Namely, there are three levels (easy, normal and advanced) and in each level the player must deliver different amount of baskets to complete the game; easy requires only two baskets to be delivered, normal requires four baskets and advanced requires the complete set, meaning eight baskets.

A tutorial was added providing simple instructions on how to perform the body movements and how to play the game. Every time the player starts a new game a message is displayed asking whether the player wants to see the tutorial before proceeding on playing.

The game does not provide any negative feedback to the user because as the design guidelines indicated it is important for the seniors to feel confident while playing the game and creating stress and anxiety has to be avoided. On the contrary, when a basket is delivered a positive message is displayed while an appropriate sound is played.

After the design process was completed, the game development was progressed in its final phase as will be described in the next section.

4 GAME TOOL DEVELOPMENT

Game tool development discussion splits into three segments. The first refers to the programming of the Kinect sensor (Kinect SDK version 2, Microsoft), the second to the creation of the game world using the Unity graphics engine (release Unity 2017.3.1f1, Unity Technologies SF Inc., San Francisco, CA) and the third to the integration of these two technologies.

4.1 Microsoft Kinect

Microsoft Kinect is a motion tracking sensor based on a depth camera recording technology for skeletal tracking (Tashev, 2013). The device combines a monochrome CMOS sensor with an infrared laser projector allowing users to interact with Kinect console or computer applications only with gestures, movements and voice commands without the need of explicitly handling a controller unit.

For the developed game tool the second version of the sensor was used (Figure 1) which is equipped with a richer SDK API, the ability to track more joints to identify hand states (Figure 2) and tools to record the motions. Furthermore, the Kinect SDK provides two machine learning algorithms, AdaBoost and Random Forest which can be trained to identify complicated activities. Such activities are recorded using the Visual Gesture Builder tool.

Figure 1: Kinect sensor v2.

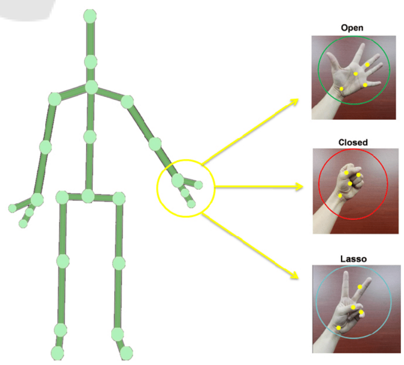

Figure 2: Kinect hand classes.

4.1.1 Activities Recording

For game activities recognition a training process was followed by using the recording tool and the machine learning algorithms of the Kinect SDK. For building the activity model the Kinect Studio tool was employed to observe the way the sensor is recording the environment. This tool facilitated also the recording of motions and gestures that were used in the game mechanics. Figure 3 shows, for example, the recording of leaning right and left motions. Such motions are stored in the form of a sequence of frames. A frame is a digitally coded static image represented as a selected number of tracked body parts (i.e. joints). A frame rate of 30 fps (a frame every 0.033sec) was used during activity recording.

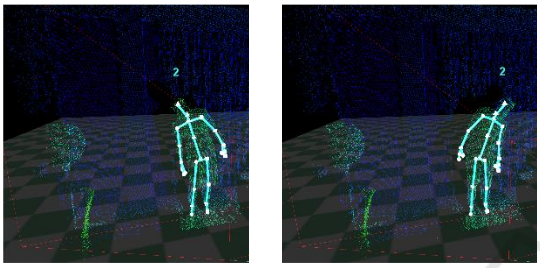

Figure 3: User leaning right and left.

During the training process one issue that required attention was the fact that different seniors have different body sizes. Thus, the system would not have been able to identify the gestures and motions if it would have been trained based on a single person. Moreover, it is expected that the elderly would not perform a specific motion in the same way. For instance it is expected that seniors would not lean left or right in the same way. To address this issue, five seniors with different weight/height characteristics were asked to perform every game activity for recording and storing the movement patterns as multiple samples.

4.1.2 Training with AdaBoost Algorithm

In order to start the training process, the pre-recorded frame files stored during the recording stage were used. The tuning of the training process entails the selection of several options. These options depend on which parts of the body the sensor will track (upper, lower or both), whether the left and right side of the user's body motion differ and whether the activities are classified as discrete or continuous.

A discrete activity is defined as a Boolean entity linked with a confidence value of existence. On the other hand, a continuous activity is associated with a progress value which allows the tool to track its progression optionally via several discrete activities. A continuous activity is more complex and it is used for motions like dancing or performing certain exercises. The machine learning algorithm that is used for discrete activities is the meta algorithm AdaBoost, whereas for continuous activities the Random Forest algorithm is used. For the goals of the game tool it was decided to classify all activities as discrete. Table 1 shows the selected options for the basic game motions.

Table 1: Selected options per motion.

Option	**Leaning**	**Walking**
Rely on joints in the lower body	False	True
Rely on hand states	False	False
Right and left side are different	True	True
Discrete/Continuous	Discrete	Discrete

The AdaBoost algorithm was used to train the recognition model for leaning and walking motions. After importing the recorded files the timestamps where the user was performing the corresponding motion were marked. Figure 4 shows the lean left and walking motions performed by a user while the blue lines represent the exact timestamp of that motion.

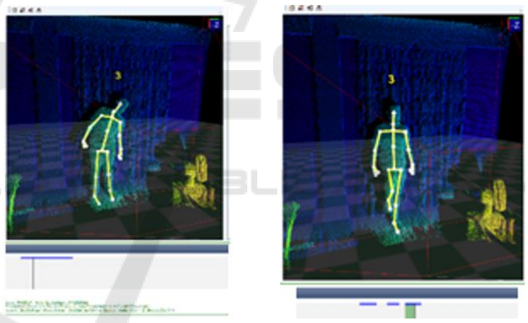

Figure 4: Training with AdaBoost for detecting leaning and walking activities.

A validation of the trained activity recognition model was performed in order ensure that the game tool identifies correctly the user's activities. The Visual Gesture Builder live testing option was used. Figure 5 shows the tool representation of a senior performing the leaning left motion. The white lines that are passing through the corresponding windows indicate the level of confidence for the gesture.

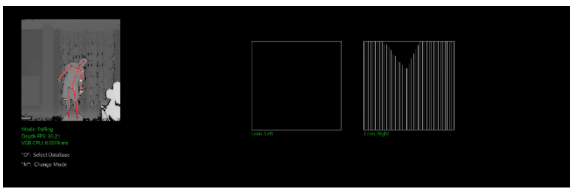

Figure 5: Validation of tracking leaning left motion.

4.2 Unity Engine – Creating the 3D Game World

Even though many other similar games reported in the literature are using a two-dimensional world a more engaging and realistic experience for the user is anticipated by playing in a three-dimensional world. In this section the steps taken to create the 3D game world are described based on the Unity cross platform game engine.

The game concept included the creation of a small village inside a forest. Firstly, the terrain on which all the game would take place was created. The terrain's main color is green embellished with some trees and flowers in order to create the forest. At the center of the forest some houses were placed to create the village. Figure 6 illustrates the final view of the village and Figure 7 depicts a view of terrain textures.

Figure 6: Overall view of the terrain.

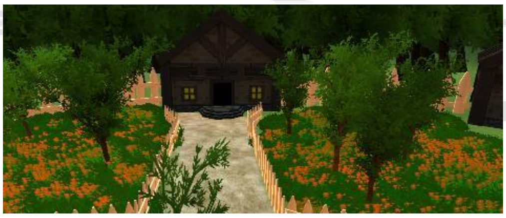

Figure 7: Textures details of the terrain.

The game scenery included a number of game objects called prefabs in Unity's terminology. A prefab can be created by the designer with random game objects or can be downloaded from the Unity's asset store (https://assetstore.unity.com/). Two assets were used to create the baskets and the fruits respectively and by combining these two, one composite game object was created, the basket filled with fruits (Figure 8). In addition, colors were added to the baskets so that the player can identify them easily.

The game concept and mechanics use Unity's particle systems. Particle systems represent the effects that take place in a game such as explosions or indicators that help the player move forward in the game. Following the HCD design guidelines, indicators were provided in the game scenario so that the player could identify straightforwardly the objects that were supposed to interact.

Figure 8: Fruit baskets as game objects.

For example, in order the player to know where to place each basket a lightning spot was created outside of a house (Figure 9). Furthermore, each spot was painted with a specific color to create a bonus option for the player. When the fruit basket and the spot had the same color the player would take double points. Therefore players had a motivation to place each basket in the same color spot and so the gaming time could be increased resulting in more user training.

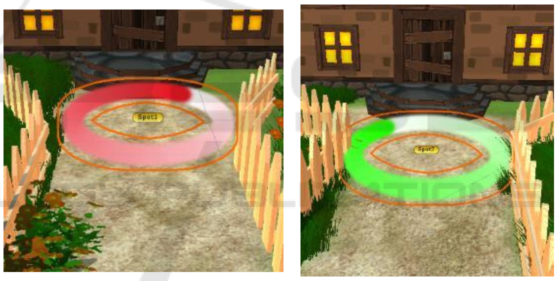

Figure 9: Spot indicators to place the baskets.

Game scenery included also colliders which helped making the game more realistic. By adding colliders in the houses, trees and fences, for example, the player could not pass through a tree or a house giving to the player the feeling of a real world.

An important step was to create the avatar that would be controlled by the user. Unity provides the prefab "First Person character" which has all the utilities needed to complete this task. Furthermore, a target in front of the avatar was added (Figure 10). The purpose of this was to provide an indication to the player on when the basket could be picked up. Thus, when the avatar is close to the basket the target becomes green otherwise the target remains white.

The game world was also enhanced with other details that, for example, would show the user information about the time and the scoring. Motivated messages and sounds were added and played each time the player was delivering a basket to the house.

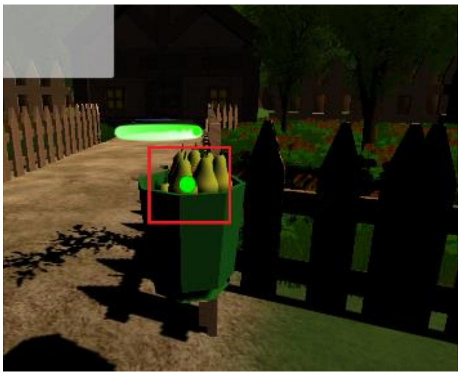

Figure 10: Player's view and target.

4.3 Integration of Kinect with Unity

Microsoft provides a library with various scripts in order to combine Unity projects with the Kinect sensor. The game tool is a combination of scripts from this library, customized scripts created and C# code added in order to retrieve data from the activities stored during the training stage and to interact with the game.

The flow of control starts with the "Body Source Manager" script which is responsible for activating and deactivating the sensor and tracking the user. This script was customized so that the on-line data from the user's activities are received and processed. Processing is done by the "Activity Detector" script.

Activity Detector receives the output from the "Body Source Manager" script and evaluates it based on the activities included in the AdaBoost's training files. A local database contains all the user's activities required to interact with the game. If the user is performing one of the stored activities a message is sent to "Kinect Manager" script.

Kinect Manager receives data indicating if the user is performing a known activity. Specifically, it evaluates the detection confidence and if this is above a defined threshold, it allows the activity to be performed inside the game. For example, if the user is leaning right and the detection confidence is above 60% then the game avatar is rotating to the right.

5 EVALUATION

The evaluation of the game tool took place at the Elderly Protection Center in the city of Ptolemaida, Greece. A group of twelve healthy seniors with an age between 61 and 85 years participated in the evaluation study (n=12, 6 male and 6 female, mean=73±6.3 years). Once informed consent was obtained the seniors were asked to play the game twice per week for a period of five weeks. In every session each senior was playing the game on all different levels for 25-35 mins. The evaluation was organized into four stages and during the whole process a physiotherapist was present for domain-specific support and a researcher for administration and technical support. There were no dropouts.

5.1 Data Collection

In the **first stage (introduction)** an overview of the technology was given and a presentation of the game tool was performed (Figure 11). The participants received information about the research goals and the scheduled tasks. They were informed about the Kinect device and its applications. From the beginning the seniors showed a great interest in the exergames concept and the supporting technology although they had no relevant experience in the past.

Figure 11: Introduction to the technology.

In the **second stage (baseline balance assessment)** the physical condition of the participants was evaluated in order to have a baseline before starting the exergaming. For this purpose, two widely accepted tests were used: the Berg Balance Scale (BBS) (Berg et al., 1992) and the 30 Seconds Sit to Stand Test (30SST).

The BBS test takes about 15 minutes and consists of fourteen exercises in order to examine and evaluate balance control. Examples of the test challenges include (Figure 12): standing for two minutes, standing unsupported with one foot in front, standing in one leg, picking up an object from standing position and moving from sit down to standup. Based on the participants' performance for each exercise a grade between 0 and 4 is given. The total score determines the balance condition as follows: a score below 20 indicates poor balance, a score between 21 and 40 indicates fair balance and a score over 40 is considered good. Table 2 provides the BBS scores per participant for the baseline stage. The average BBS score was 49.8 (SD ±0.9) which indicates a good baseline balance for the study sample.

The 30SST is a simple exercise to assess the muscle strength of the participants. The senior is asked to sit in a chair and stand up as many times as possible in 30 seconds without any help. Table 3 provides the 30SST scores per participant for the baseline stage. The averagescore was 13 (SD ±1.7).

Figure 12: Seniors standing on one leg (left photo) and with one foot in front (right photo) during BBS test.

The overall outcome of the baseline physical condition assessment was that all participants had relatively high scores and therefore there was no high risk of falling during the game.

In the **third stage (exergaming)** the participants played the game (Figure 13). In particular, each senior started with the easy level and continued to the next one up to the advanced level. During exergaming various parameters were recorded like the playing time, the collected points and whether the participant completed the level or stopped and quit. In the initial sessions, while all the participants completed the first and second level, many of them had to stop prematurely the advanced level due to tiredness. After some sessions however they were able to complete all game levels. It is worth mentioning that during this stage there were requests by more seniors of the Elderly Center to play the game. They had the opportunity to play sometimes the game but their statistics were not recorded because they didn't participate in the study from the beginning.

In the **fourth stage (post exergaming balance and usability assessment)** the participants repeated the two balance tests to evaluate the effect of exergaming in their performance. Table 2 and Table 3 summarize the results by comparing the baseline and post exergaming scores. The average BBS score after exergaming was improved to 50.3 (SD ±0.8) (50% of the participants experienced an improvement in their balance) while the average 30SST score was slightly improved to 13.4 (SD ±1.2). Given the good scores from the baseline stage and the limited timeframe of the study the overall balance improvements attained were considered positive.

Figure 13: Seniors playing the game.

Table 2: BBS scores pre and post exergaming.

Participant ID	Baseline Score	Post exergaming Score	Difference
1	50	50	0
2	50	51	+1
3	50	50	0
4	50	50	0
5	51	51	0
6	51	52	+1
7	50	50	0
8	51	51	0
9	49	50	+1
10	48	49	+1
11	49	50	+1
12	49	50	+1

Table 3: 30SST scores pre and post exergaming.

Participant ID	Baseline Score	Post exergaming Score	Difference
1	11	12	+1
2	11	12	+1
3	13	13	0
4	15	15	0
5	14	14	0
6	10	12	+2
7	13	13	0
8	14	14	0
9	16	16	0
10	13	14	+1
11	13	13	0
12	13	13	0

The usability of the game tool and the exergaming experience and satisfaction of seniors were assessed using the system usability scale (SUS) and a semi-structured interview. SUS is a 10-item questionnaire with five response options from strongly disagree to strongly agree (Brooke, 1996). SUS items were adapted to make questions relevant for this study. Examples of items used are the following:

I think that I would like to use this exergame frequently;

I thought the exergame was easy to use;

I found that the various functions in this exergame were well integrated;

I thought there was too much inconsistency in this exergame.

The participant's grades for each item were processed so that the original scores of 0-40 are converted to 0-100. Except from three seniors who rated the exergame tool as acceptable (scores 75-78) all the other scores were above 80. The average SUS score was 84.3 out of 100, suggesting high user acceptance (Bangor et al., 2008).

5.2 Data Analysis

The quantitative and qualitative data collected during the study were analyzed to identify the impact of the proposed exergame.

Statistical analysis using Wilcoxon signed-ranks test (due to non-normality of the data) for paired samples and a level of significance (a=0.05) was applied to compare the BBS and 30SST scores between pre and post exergaming. The results shown in Table 4 indicate that the BBS score improvement between the pre and post exergaming periods is statistically significant ($p < 0.05$), whereas the 30SST score improvement is statistically marginally significant ($p=0.05$). The walking and leaning motions included in the exergame design could explain the improvements as these movements contribute in maintaining both motor and balance function.

Table 4: Statistics of BBS and 30SST.

Metric	Pre	Post	Diff	p-value
BBS	49.8 (±0.9)	50.3 (±0.8)	0.5	0.007
30SST	13 (±1.7)	13.4 (±1.2)	0.4	0.05

The interview with the seniors showed that 100% of the participants found the exergame to be enjoyable, 80% thought that the movements were not complicated but easy to remember and 90% of them expressed their expectation to use the exergame after the study. Positive comments were provided for the game theme and the extensionality of the 3D textures as well as the seamless navigation of the game through the player avatar. Comments also provided that their confidence on the technology increased due to their experience with the game tool. The interview with the expert gave the feedback that the use of the game not only helped the seniors to improve their physical state but contributed to the improvement of their psychological and emotional state as they were happy when playing the game and throughout the duration of the study there was a positive feeling and anticipation towards the planned activities.

The performance statistics exported by the system indicated an improvement on the game completion time per level throughout the timeframe of the study. In particular, for the easy level the average completion time for all participants was reduced from 358 to 254 secs (29.1%), for the normal level from 540 to 485 secs (10.2%) and for the advanced level from 1000 to 917 secs (8.3%). Figure 14 illustrates the progress of the average game completion time throughout the study for the three game levels.

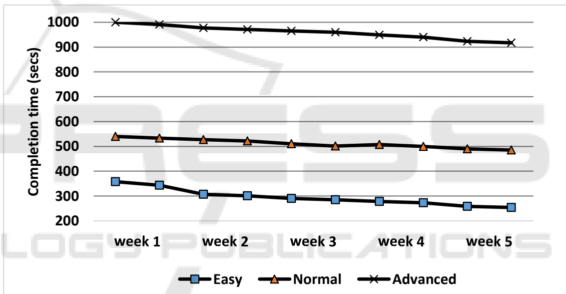

Figure 14: Average game completion time progress.

All the participants expressed high willingness to use the exergame for improving their physical condition. This situation was reflected both in their SUS score and during the interview discussions. Another indicator of participant's interest towards the game is given in Figure 15 which shows the number of the baskets the players delivered in the advanced level. In the first two weeks due to physical tiredness the average baskets delivered was less than the threshold to complete the level. However, from week 3 until the end of the study all the participants were able to complete the advanced level.

Limitations of the current study are acknowledged. The limited number of participants and the short evaluation timeframe prevent the justification of more sound results. Achieving substantial balance improvements in elderly requires playing the games over 3 times per week for at least 3 months (Agmon et al., 2011). In comparison, the duration of this study was 5 weeks with 2 game sessions per week. Although the BBS score was improved after the exergaming intervention the lack of a control group leaves a vagueness whether the source of improvement was the exergame alone.

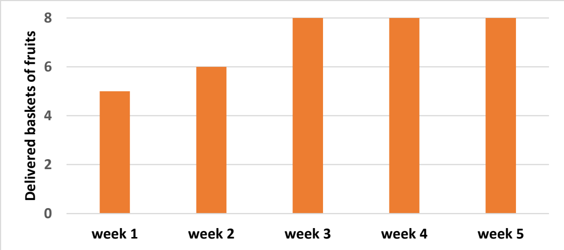

Figure 15: Average number of delivered baskets in the advanced level.

6 CONCLUSIONS

This paper argued and provided evidence that exergames for seniors, if properly designed, can be an enjoyable tool for balance training leading to improvements in physical health conditions.

Using the Kinect technology for exergame development enables the unobtrusive sensing of gestures and motions integrated in the game scenario while providing seniors with a natural way to validate their movements through the tool feedback. Given the low cost of the sensor device and its portability the tool can be deployed and used in settings ranging from homes to facility centers supporting the elderly.

Furthermore, developing such games using a three-dimensional rather than a two-dimensional world makes such systems more realistic and thus more attractive to use by the elderly.

Work in progress includes adding more features to the game tool such as multiplayer mode where seniors could either play against each other or preferably collaborate to complete the game faster. In addition, daily missions (such as “Deliver two baskets under x min”) would increase challenges for more demanding users. Leveraging on game data analysis and learning techniques a research direction to be explored is the automatic adaptation of game variables based on additional context such as environmental attributes and individual user characteristics. Finally, an evaluation study with a larger sample of seniors, including a control group, and for a longer period of time would provide a more sound justification of the present results.

ACKNOWLEDGEMENTS

The evaluation took place at the Elderly Protection Center in the city of Ptolemaida, Greece. The authors wish to thank the volunteers that took part in the evaluation as well as the medical experts for their valuable contribution in this study.

REFERENCES

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, vol. 34, no. 4, pp. 161-167*.

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, vol. 98, no. 3, pp. 211-216.*

Bangor, A., Kortum, P. T., Miller, J. T. 2008. An empirical evaluation of the system usability scale. *Intl. Journal of Human–Computer Interaction, vol. 24, no.6, pp. 574-594.*

Berg, K. O., Wood-Dauphinee, S. L., Williams, J. I., Maki, B. 1992. Measuring balance in the elderly: validation of an instrument. *Canadian journal of public health, vol. 83, pp. S7-S11*.

Brauner, P., Ziefle, M. 2015. Exergames for Elderly in Ambient Assisted Living Environments. *In Internet of Things. User-Centric IoT, pp. 145-150.* Springer, Cham.

Brooke, J. 1996. SUS-A quick and dirty usability scale. *Usability evaluation in industry, vol. 189, no. 194, pp. 4-7.*

Brox, E., Konstantinidis, S. T., Evertsen, G. (2017). User-centered design of serious games for older adults following 3 years of experience with exergames for seniors: A study design. *JMIR serious games, 5(1)*.

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, vol. 15, no. 1, 106*.

Gerling, K., Livingston, I., Nacke, L., Mandryk, R. 2012. Full-body motion-based game interaction for older adults. *In SIGCHI conference on human factors in computing systems, pp. 1873-1882*.

Gerling, K.M., Schulte, F.P., Smeddinck, J., Masuch, M., 2012. Game design for older adults: Effects of age-related changes on structural elements of digital games. *In International Conference on Entertainment Computing, pp. 235-242*.

Goble, D.J., Cone, B.L., Fling, B.W., 2014. Using the Wii Fit as a tool for balance assessment and neurorehabilitation: the first half decade of “Wii-search”. *Journal of neuroengineering and rehabilitation, vol. 11, no. 12, pp. 1-9.*

Korn, O., Brach, M., Hauer, K., Unkauf, S. 2013. Exergames for elderly persons: Physical exercise software based on motion tracking within the framework of ambient assisted living. *In Serious Games and Virtual Worlds in Education, Professional Development, and Healthcare, pp. 258-268*. IGI Global.

Lamoth, C.J.C., Caljouw, S.R., Postema, K., 2011. Active video gaming to improve balance in the elderly. *Studies in Health Technologies and Informatics, vol. 167, pp. 159-164.*

Lange, B., Flynn, S., Rizzo, A., 2009. Initial usability assessment of off-the-shelf video game consoles for clinical game-based motor rehabilitation. *Physical Therapy Reviews, vol. 14, no. 5, pp. 355-363*.

Mousavi Hondori, H., Khademi, M. 2014. A review on technical and clinical impact of microsoft kinect on physical therapy and rehabilitation. *Journal of medical engineering, vol. 2014, no. 846514*.

Planinc, R., Nake, I., Kampel, M., 2013. Exergame design guidelines for enhancing elderly's physical and social activities. *In AMBIENT 2013, The Third International Conference on Ambient Computing, Applications, Services and Technologies, pp. 58-63*.

Sato, K., Kuroki, K., Saiki, S., Nagatomi, R. 2015. Improving walking, muscle strength, and balance in the elderly with an exergame using Kinect: A randomized controlled trial. *Games for health journal, vol. 4, no.3, pp. 161-167*.

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J.C.T., Lord, S.R., 2011. Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *New South Wales public health bulletin, vol. 22, pp. 78-83.*

Sugarman, H., Weisel-Eichler, A., Burstin, A., Brown, R., 2009. Use of the Wii Fit system for the treatment of balance problems in the elderly: A feasibility study. *In Virtual Rehabilitation International Conference, pp. 111-116*.

Tashev, I. 2013. Kinect development kit: A toolkit for gesture-and speech-based human-machine interaction. *IEEE Signal Processing Magazine, vol. 30, no. 5, pp. 129-131*.

Van Diest, M., Lamoth, C.J.C., 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, vol. 10, no. 1, pp. 101*.

Weisman, S. 1983. Computer games for the frail elderly. *The Gerontologist, vol. 23, no. 4, pp. 361-363.*

Wever, R., Van Kuijk, J., Boks, C. 2008. User- centred design for sustainable behaviour. *International journal of sustainable engineering, vol. 1, no.1, pp. 9-20.*