Participatory Design of Fall Prevention Exergames using Multiple Enabling Technologies

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Abstract: Exergames provide significant health benefits for older people. In particular, reinforcing strength and balance through exercises is an effective measure to prevent falls. In addition, cognitive improvements and mental benefits for the elderly can be achieved through physical activity tasks. In this paper a new exergame platform is introduced that combines hardware and intelligent software to create adaptable gaming experiences to improve physical and cognitive functions of older people. The platform integrates different enabling technologies (motion recognition sensor, virtual reality and smart floor) to provide the user with a wider variety of interactions and exercises. The design and development of the exergames is based on the principles of human centered and participatory design as this approach is particularly suitable for the development of technological solutions targeted towards the elderly. In this context, the main methods applied are the development of prototypes and use of qualitative research methods such as participatory development with the help of a focus group using interviews, questionnaires and end user observation. Representative exergames were presented in the form of high and low fidelity prototypes for feedback to both end users and healthcare experts. The data collected from a focus group workshop have been analyzed in order to provide the main guidelines and to record aspects that require attention in the design and implementation of the exergames.

1 INTRODUCTION

In 2050 the world population of the elderly (aged 65 and over) is estimated to be 1.5 billion (United Nations, 2020). While long living is an important accomplishment of the present societies, the cost of ineffective aging is significant both individually and socially. Interventions that can support effective aging are therefore of great importance to improve the quality of life and well-being of older people.

On the other hand, even normal aging has a detrimental effect on the body and the mind associated also with the increased risk of falling (Melzer et al., 2004). Falls have significant consequences for the elderly, as the feeling of fear develops strongly, resulting in a negative impact on their behavior, causing in general the avoidance of activities. Moreover, according to studies, 5-20% of falls have serious consequences, such as head injuries, fractures and in extreme cases immobility or even death (Sterling et al., 2001). The large increase of elderly falling cases makes research targeting their prevention an important public health priority. Studies have shown that systems directed at improving the physical condition of the elderly lead to a reduction of up to 50% in the risk of falling (Gillespie et al., 2012).

Recently the development of systems that support exercising in the form of games (exergames) has been observed. These systems have been proven to be safe for the elderly and help improve both cognitive and physical functions to a greater extent than traditional ways of practice, mainly due to the motivation they provide to users (e.g. entertainment, challenges in the form of different difficulty levels, scoreboards etc.) (Skjæret et al., 2016). The critical question, however, is whether these systems are easy for the general public to use. Research has shown that although existing systems help significantly to reduce the risk of falling, it is, still, difficult to use them by people who are unfamiliar with this technology, such as the elderly (Nyman et al., 2012). Moreover, the lack of a simple interface often makes their adoption difficult.

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Most systems have been developed using sensors that are provided by commercial gaming machines such as Nintendo Wii, and Microsoft Kinect Xbox. However, the games that have been designed are not adapted for the elderly as there is often difficulty both in using and in understanding them, so the presence of a third more experienced person is always required to guide the users (Valenzuela et al., 2018). It is understood that such a situation prevents older people from using this technology while creating a feeling of fear and lack of confidence.

In addition, with the recent emergence of virtual reality technology, a new way of practice is emerging in a more realistic environment (Xu et al., 2020). In addition to the physical condition, studies have shown that using this technology can bring improvements on cognitive skills. On the other hand, even this practice is aimed mainly at young people familiar with the technology. Furthermore, its usage becomes even more difficult as it requires the use of one or two additional remote controls.

With technology rapidly evolving, advanced systems tend to become accessible by all citizens. It is therefore important to determine not only the effectiveness of games in terms of physical and cognitive improvement but also to identify the most appropriate technologies to be applied in order to ensure the safety of older people in different situations. The development of a platform that combines new technologies and provides solutions to fill gaps and shortcomings in existing systems is therefore necessary.

In this paper, a new exergame platform, developed in the context of the GAME2AWE project (https://game2awe.aegean.gr/), is introduced that combines hardware and intelligent software to create adaptable gaming experiences to improve physical and cognitive functions of older people. GAME2AWE aims to develop a platform for game-based exercise applications suitable for the elderly by integrating innovative features that combined are not provided by existing systems, to the best of our knowledge. The objectives of GAME2AWE are served by the following research and development activities:

- Design of games suitable for the elderly following a human centered design approach regarding game mechanics specification by involving all relevant stakeholders (elderly, caregivers, medical experts, system and game engineers) in all phases of system development.
- Combining multiple technologies for the development of the GAME2AWE platform in order to support multimodal interactions (voice, gestures, movement and touch) which can facilitate the implementation of game scenarios in a way that motivates and enhances users' autonomy while making the platform easy to use.
- Design and construction of a robotic tile as a component for the assembly of a smart floor which will serve as an autonomous computing platform for the deployment of games that train motor and cognitive functions.
- Integration of measures in the game mechanics that have been proven to predict the risk of falling, such as the Choice Step Reaction Time (Lord and Fitzpatrick, 2001), providing the potential for using the platform as a diagnostic tool.
- Application of machine learning algorithms to analyze the data collected by the platform in order to: a) define more effective exercise programs by adapting the difficulty level to the profile of each user; b) train a model to classify users at cognitive and motor levels according to their performance.
- Evaluation of the game platform in three dimensions (motor, cognitive and technological) by applying a randomized controlled trial and using valid relevant scales.

For the development of the exergames a first inventory of potential games in the form of scenarios and key features was assembled based on relevant studies (Sato et al., 2015; Shaw et al., 2015; Skjæret et al., 2016; Xu et al., 2020) and our own relevant experiences (Kostaki and Goumopoulos, 2016; Chartomatsidis and Goumopoulos, 2019). Subsequently, in order to meet the above-mentioned objectives, representative scenarios were selected from two main themes "Life on a Farm" and "Fun Park Tour", and were presented for feedback to both end users and healthcare experts within a focus group. The data collected from the focus group workshop were analyzed in order to provide the main guidelines and to record aspects that require attention in the design and implementation of the exergames.

The rest of the paper is organized as follows. Section 2 explores the topic of physical activity. Recommendations proposed for physical activity by organizations and relevant literature with a focus on fall prevention are reported. Sections 3 and 4 discuss the methodology that frames the development of the platform and the participatory design of the exergames. Finally, the conclusions are given.

2 PHYSICAL EXERCISE RECOMMENDATIONS FOR THE ELDERLY

The World Health Organization (WHO) and other associations have made recommendations for physical activity referring to adults over 65 years of age according to which elderly people should perform 150 minutes of moderate aerobic activity weekly, or alternatively 75 minutes of intense aerobic activity (American College of Sports Medicine, 2013). A combination of moderate and intense exercise during the week is an alternative option. For example, moderate physical activity may include activities such as walking at a regular and quicker pace, housework, woodworking, cutting the grass and dancing. Intense physical activity, on the other hand, includes jogging and running, construction work, farming, swimming and cycling.

Aerobic activities are also recommended to take place in sessions of ten minutes at the minimum and to combine exercises for strengthening muscle power two or more times a week. The WHO highlights physical activities that enhance the balance for seniors with low mobility capacity. Performing these exercises thrice each week can lead up to 30% reduction of the falling risk (World Health Organization, 2008). If the recommendations on exercising cannot be reached, because of health problems, the elderly adults should aim to be as energetic as possible in a safe manner that improves their physical condition. In addition, exercising five hours a week, corresponding to moderate aerobic activity of 300 minutes, or intense aerobic activity of 150 minutes, renders greater health benefits such as reduced risk of harmful weight and chronic diseases.

GAME2AWE aims to offer physical activity opportunities to older people who experience physical and cognitive impairment due to aging. The most frequent expected impairment will be associated with muscle weakness due to elderliness, which can lead to falls and other health problems. In this context, it is important to categorize the games and the exercises involved according to the needs and physical abilities of each user.

The review of relevant literature has shown that strengthening and balance exercises are suitable for reducing the risk of falling (World Health Organization, 2008; Tucker et al., 2011; Kiselev et al., 2015). In this direction, the identification of suitable exercises to be used in the exergame platform is important. Physiotherapists suggest stepping exercises as appropriate, because they have found that performance in such exercises can be a good predictor of falls. It also turns out that a recurring exercise program with stepping exercises can improve the balance in the elderly. Stepping exercise requires significant physical activity, which is useful for improving physical health. Stepping or walking exercises are also recommended by bodies such as WHO, the European Health Directorate and the US Department of Health and Human Services.

Some of the exercises included in the exergames of the GAME2AWE platform are: ‘walking in standing or sitting position’, ‘weight shifting in standing or sitting position’, ‘standing on one leg’, ‘foot stretching’; ‘flank stretching’, ‘weight shifting to both sides in standing position’, ‘weight shifting forwards and backwards in standing position’, ‘leg lifting’ and ‘from chair sitting to standing position’.

3 METHODOLOGY

Our approach is based on the activity theory of aging, according to which an active lifestyle leads to greater health both physically and mentally and better quality of life (Lemon et al., 1972). In contrast, a sedentary lifestyle leads to health deterioration and unsuccessful aging (Brown et al., 2008). Against this background, exergaming is a promising approach to reinforce the strength and balance of older people, as exergames can improve both cognitive and motor capabilities.

3.1 Technologies

One of the most well-known technologies used in exergames is the Microsoft Kinect motion sensor (Zhang, 2012), which allows the user to interact with the computer through the use of gestures, movements and voice commands. In particular, Kinect 2.0 is an interactive motion detection device consisting of an infrared (IR) projector, an IR camera, an RGB camera and a multidimensional microphone. It also supports voice input and recognition. Kinect can detect in real time a human body (or multiple bodies) and locate its skeletal structure, in terms of a 25-joint skeletal model, when an individual is in sight. Thus, users do not need to wear sensors since system interactions can be realized through diverse movements and gestures. Kinect streamlines interactions and enables more natural communications, making it easier for the user to engage with the game.

The integration of Kinect in exergames and its positive contribution regarding the improvement of strength, endurance and balance of the elderly has

been reported in several studies (Sato et al., 2015; Skjæret et al., 2016). The low cost of the equipment makes it accessible to the elderly and allows even for daily exercise at home.

Figure 1 illustrates an example exergame foreseen in the GAME2AWE platform using the Kinect motion sensor. In this scenario, the players' mission is to collect olives from an olive tree land in the digital space of a series of games called "Life on a Farm". The mechanics of the game incorporate movements which were selected as appropriate exercises for fall prevention while at the same time serving a specific goal in the gameplay. For example, side steps are used for selecting a tree to harvest. A rowing movement is used for spreading the olive collection sheet, while arms lifting is used for harvesting crops. In more advanced levels of the game more demanding movements are required for harvesting, such as flank stretching with arm lifting and standing on one leg with arm lifting.

Figure 1: An example game using Kinect sensor in the "Life on a Farm" theme of the GAME2AWE platform.

Virtual reality (VR) technology presents a three-dimensional virtual world in which a person can move and interact with objects around her, giving the user the feeling that she is actually in the virtual world. From a technical point of view, VR systems are built on three concepts: Interaction, Imagination and Immersion (Sheridan, 2000). Interaction refers to the ability of shaping the virtual world according to the user's actions and the user's ability to interact with objects in the virtual world. Imagination is the ability to perceive the virtual world and its components as real. Immersion is the degree to which we can perceive our presence in a non-real world as natural.

Utilizing VR technology can greatly benefit the elderly in terms of cognitive stimulation. VR creates an interactive and immersive environment that gives users the impression of joining a virtual world. This technology allows the elderly to visit various places, immersed in a virtual setting that would normally be quite dangerous or too far away or impossible to occur due to health problems (Xu et al., 2020). Figure 2 illustrates an example VR game that is foreseen in the GAME2AWE platform to train cognitive skills such as visual perception, concentration and problem solving. This game belongs to a series of games within a common theme called "Fun Park Tour". It refers to a virtual tour in a park where the user can choose to play games that have a fun character while at the same time it is required to perform movements that are relevant to fall prevention.

Figure 2: An example VR game in the "Fun Park Tour" theme of the GAME2AWE platform.

Although VR is a technology with several design challenges, when used in exercise games (Shaw et al., 2015), it has been shown to provide a safe and appropriate environment that can be adapted to the needs of each user. The use of this technology has a positive effect on the elderly with chronic diseases such as dementia, improving both their physical and cognitive status (Eisapour et al., 2018). Apart from cases of dementia, VR has been applied to other diseases such as musculoskeletal and post-cerebral rehabilitation (Gervasi et al., 2010). Researchers have used VR-based commercial exergames that aim to enhance various physical functions in the elderly, such as balance and strength. The effectiveness of VR technology in reducing the risk of falling, for example, has been explored at a preliminary level (de Melo et al., 2018).

Moreover, although systems incorporating VR have proven to be effective in improving the motor and cognitive condition of older people, an obstacle often encountered is the need to have one or two additional remote controllers which may not be acceptable by older people. GAME2AWE proposes a combination of camera motion recognition technology (Kinect sensor) and VR aiming at removing additional sensors from the user thus providing greater freedom of movement.

Augmented reality (AR) varies from VR as it involves the introduction of virtual entities into the real environment, instead of the creation of a completely virtual space. It usually includes an indirect representation of the real environment, with

virtual features and information, thus enhancing the user's sense of reality. Mixed reality (MR) is described as a wide intersection between VR and AR, which integrates 3-D holograms into the real environment. These forms of technology include applications aimed at cognitive practice, which includes decision-making and learning in a virtual environment (Aruanno and Garzotto, 2019).

Another way of exercising that is explored is through the use of an interactive mat or floor (Heller et al., 2014). The smart floor offers the ability to create an integrated system with autonomous power without the use of additional equipment such as computers or power supply. The information is transferred by the user to the floor through pressure which is measured from embedded sensors on the floor. In GAME2AWE platform, the smart floor has a modular structure (puzzle format) making it easy to assemble and adapt it to any space (Figure 3).

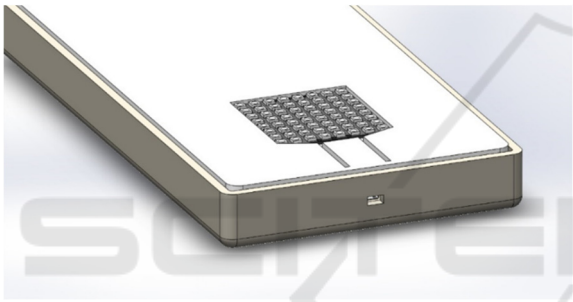

Figure 3: Smart floor module model in the GAME2AWE platform.

Technologies that do not require the use of a complex user interaction environment such as the proposed smart floor are more suitable for the elderly to improve their physical and cognitive functions. The smart floor will be used as a large touch screen to project motion patterns that users individually or in groups should follow in the scenario of a game. For example, in the dancing game, foreseen in the GAME2AWE platform, there are predefined shapes (arrows) on each tile of the smart floor. The smart floor displays one of these shapes and the user is asked to step on the tile with the corresponding shape within a timeframe.

Another objective served by the smart floor is the integration of the Choice Step Reaction Time (CSRT) metric in the games as a predictor of falling risk. Participants are asked to take quick steps in response to the corresponding visual stimuli presented randomly on the tiles and return back to their original position. CSRT is measured in milliseconds and may be broken down into three components: a) reaction time, i.e., the time from the presentation of the stimulus to the lifting of the foot; b) motion time, i.e., the time from the lifting of the foot to the contact of the foot on the lightened tile; c) total response time, i.e., the sum of reaction and motion time. According to the study of Lord and Fitzpatrick (2001), elderly who are prone to fall have significantly increased CSRT times (1322±331 msec) compared to elderly people who are not prone to fall (1168±203 msec).

3.2 Architecture

GAME2AWE proposes an innovative combination of motion detection technology, VR and smart floor thus providing the user with a greater variety of interactions and exercises. The architecture of the GAME2AWE platform is illustrated in Figure 4. The Device Layer is the first level of the platform architecture, where external devices communicate with the system. The information collected by the devices is forwarded to the Data Layer where it is modeled using machine learning algorithms. The information is then classified by the Analysis Layer for the purpose of accepting or rejecting an action/movement. In case of acceptance, information is perceived by the user through Game Mechanics. The game mechanisms inform the system about the progress of the user in the gameplay in order to make the corresponding adaptation of the game parameters. The Adaptation Layer defines how to communicate from a set of services to and from the Interaction Layer. Finally, the Interaction Layer provides the user interfaces.

The Adaptation Layer (AL) is an important module of the architecture that provides the system intelligence to create adaptable gaming experiences. The AL is responsible for adjusting the parameters and elements of each game. A key topic in the design of the AL is to provide the ability to adapt the elements that are related to the difficulty level of the game. The games in the platform contain a variety of parameters that can be used for the adaptation process. For example, in the olive harvest game (Figure 1) such parameters include the number of trees, the crop type, color, and the growing frequency. The input data that the AL will use to make decisions on the configuration of the gameplay parameters will be derived both from the data of the current game round as well as from the corresponding performance data from previous game sessions, which will be retrieved from the data repository. This data will be processed and given as input to machine learning models. The result will be a set of parameters that will regulate the adaptable elements of the game.

Figure 4: GAME2AWE platform architecture.

The use of machine learning models is justified by the fact that the parameters to adjust for each game will usually be more than one, and the degree of variation for each of them would be different in each step, which means that it would be extremely difficult to rely is simple conditional statements in order to build the decision logic.

3.3 Development and Evaluation

Human centered design according to ISO 13407 (International Organization for Standardization, 1999) for interactive applications is followed for the development of the exergame applications. The design is based on an iterative process where face-to-face meetings take place at the initial stage between the application development team, the elderly and health specialists (physiotherapists, orthopedics, psychologists) who are invited to identify possible interaction activities and the basic mechanisms related to the interventional goals of each game. A focus group is created to help refine the characteristics of each game and the body movements that will be used to empower the elderly during the game. By capturing the initial plan of the application, a quick prototype of the game concept is implemented, which is given to users for evaluation. The development team responsible for analyzing user assessments and for confirming the suitability of the prototype usage, takes an active role at this stage. This is followed by a redesign phase with improved game rules and interactions prior to the final development of the prototype.

The evaluation of the platform includes three dimensions: motor, cognitive and technological. A total of 60 users are foreseen and their participation is based on age (≥65 years) and health criteria (possibility of independent movement, absence of serious health problems). The methodology includes a control group and an intervention group using a randomized controlled trial. For all users, measurements of motor and cognitive functions will be recorded before and after the use of GAME2AWE exergames. The intervention group will use the GAME2AWE platform 1-2 times a week until each participant completes 24 sessions. Valid relevant tests/scales will be used for the motor axis such as: 30 Second Sit to Stand Test (30SST), Berg Balance Scale (BBS), Choice Stepping Reaction Time (CSRT), Functional Reach Test (FRT) and Time Up and Go (TUG). The Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) scales will be used for the cognitive axis. For the technological acceptance of the platform by users, parameters such as Perceived Usefulness, Perceived Ease of Use and Output Quality (Technology Acceptance Model 3) are evaluated. The Physical Activity Enjoyment Scale (PACES) will be used to assess user satisfaction. Qualitative research will be carried out through semi-structured interviews with the users participating in the pilot study. This research will also identify subjectively the measure of quality of life improvement. The following functions will be examined by experts to assess the improvement brought by the use of the GAME2AWE platform: walking, muscle strengthening, balance, space-time orientation, attention, concentration, memory and observation.

During the use of the platform, the system collects and stores encrypted performance data such as game scores, interaction time with the game screens, game usage frequency, games successfully completed, number of errors, etc. The platform relies on pseudonymisation to store users and connect them to the corresponding information collected from them. The stored data is used by machine learning algorithms to define more effective exercise programs to reinforce balance and strength in order to prevent falls and improve cognitive abilities. In addition, the discovery of patterns in stored data will be exploited to classify older people at diagnostic levels in order to complement traditional diagnostic tools.

The research data to be collected during the evaluation of the game platform will comply with the requirements of the legislation on the protection of

personal data and in particular with the General Data Protection Regulation. The participation of users in the research will require their written consent in accordance with ethics and ethical rules in scientific research.

4 DESIGNING EXERGAMES WITH A FOCUS GROUP

4.1 General Observations

There are many important questions that need to be answered in order to create an exergaming technology that is suitable for the elderly. Motivating people to physical activity is not always an easy task and this can be particularly true for older people. Studies have shown that exergames by their nature motivate the elderly to exercise as long as they provide enjoyment at the same time as exercising.

The social interaction that can occur when playing games in groups is also an important incentive that enhances the eagerness for using exergames and should be taken into account in the design of games. Even the choice of the appropriate music and more generally the sound stimuli provided by the application to enhance the exercise experience can be a positive incentive for the continuation of exercises.

In principle, the different needs and expectations of older people must be understood, while taking into account their different characteristics. Contact with end users is important to meet these needs. A key element is therefore the involvement of the elderly in the process of developing applications following a human centered design approach. The involvement of health and care experts is also very important for example in selecting appropriate exercises and integrating them into games. Under this approach tools that can help are, for example, interviews and focus groups (Dwivedi et al., 2012).

4.2 Focus Group Workshop

A qualitative research was carried out using a focus group (FG) that is considered vital in the human centered design process adopted for the exergames development. The research was carried out through a coordinated group discussion based on the perceptions and experiences of the participants. It was thought that a group discussion would encourage participants to share experiences in order to draw useful conclusions. Basic rules were followed which argue that a FG workshop should last one to two hours and have 6-12 participants. Questions should be asked in such a way that participants can express their views and are not limited to ‘yes’ or ‘no’ answers (Bruseberg and McDonagh, 2002).

The FG workshop took place in September 2021 in the facilities of a daily care center for elderly and lasted 2 hours. Participants after being informed of the objectives of the meeting validated their voluntary participation by accepting the terms and signing the relevant consent document. The FG sample consisted of all the main stakeholders planned to be involved in the design of the game platform (i.e., elderly, care givers, health specialists and system engineers). The FG workshop was conducted with eleven participants (N=11) which were categorized into two primary roles: elderly as end users and domain experts. Table 1 contains basic demographic features of the FG.

Table 1: Basic demographics of the Focus Group.

Characteristic	Experts	End Users
N	5	6
Age (avg ±stdev)	37.2 ±7.91	68.5 ±11.64
Gender (male/female)	2/3	1/5
Education years	≥16	9.66 ±4.27
Technology familiarity*	4	2.16 ±1.72

*Technology familiarity (e.g. frequency of internet usage and computing devices) was assessed with relevant questionnaire items in a scale of 0 to 4.

In this context, a brief introduction was provided by the scientific coordinator of the study on the objectives of the meeting and the technologies to be used. Then game concepts and scenarios were presented in two stages and at each stage a group discussion was held which was structured in order to collect appropriate information that will contribute to the better design of the exergames. Prototypes from a previous study (Chartomatsidis and Goumopoulos, 2019) were also demonstrated. As the end users had not any previous experience with exergames, launching the discussion through the presentation of relevant applications was deemed necessary to prepare the ground for the discussion. By using brainstorming and observation techniques as well as an informal interview with the members of the FG, helped to capture experiences and opinions, as design and operational issues of the exergames were discussed more thoroughly.

Representative scenarios from two game themes (“Life on a Farm” and “Fun Park Tour”) were presented to the end users and healthcare experts for feedback. The objectives of the discussion in the FG can be summarized as follows:

- Involvement of stakeholders (end users, experts) in the process of developing the exergames;
- Discussion on game themes;
- Evaluation of game scenarios/designs;
- Clarity of game goals;
- User interface simplicity;
- Multiplayer support;
- Feedback on prototypes to create friendly games for the target user group;
- Assessment of suitability and safety of exercises and movements incorporated in the game flow.

A discussion guide was used, but at the same time an attempt was made to make the conversation as open as possible. The discussion concerned the game scenarios/prototypes presented. The discussion guide included questions organized in categories as follows:

General questions

Is this the first time you've seen games that use the technologies presented?

If so, what have you used in the past?

In what context?

In general, have you ever played computer games?

If so, on which platform?

Usefulness of applications/games developed using the technologies presented

Motivation to exercising?

Improvement on:

- Physical condition
- Cognitive skills
- Mood
- Self-confidence
- Socialization

Could you think of incentives that can help older people to use such applications?

Could you think of some obstacles refraining older people from using such applications?

What other services/functionality could be integrated into the platform to better support end users with respect to exercising?

General understanding of the subject of the game, its gameplay and its elements

How does it work?

How are the points earned?

What do the different levels of difficulty mean and how are they displayed on the screen?

What do you think of combining physical exercises with cognitive challenges during the game?

Music and sounds in the game?

What do you think of the idea of a series of games, where new games will be accessed with a small cost?

The climate was positive and the interactive conversation was very efficient as a climate of trust and intimacy was established which allowed all participants to give responses, make suggestions for improvement and even develop a dialogue between them without the need for the intervention of the researchers.

4.3 Data Analysis

Analyzing the data collected in the context of a qualitative research is very important, as the conclusions drawn will essentially help to better design the exergames.

Therefore, the data collected from the FG workshop, including recordings, handwritten notes and the reactions during the presentations, were analyzed. By recording gestures, facial expressions, tone change, and voice intensity, it was possible to grasp any enjoyment, difficulty or contrast to game elements. Such information is equally important for drawing useful conclusions. For example, when end users wanted to indicate new themes in games they spoke calmly and comprehensively, while in points that did not agree with the structure of the user interface, the volume of their voice increased, which testified to their opposition. There was also an attempt to decode and isolate words or expressions used by the FG members, such as difficulty, flexibility, pleasant, obscure, etc.

The main findings of the group discussion held during the FG workshop are summarized below. The findings are based on the comments of the participants and the observation of their reactions during the presentation of the game scenarios and prototypes.

After the presentation of the first set of games (theme “Life on a Farm”) it took some time before end users made their observations. It turned out that it was not clear to them from the presentation how these games work in practice. When it was explained that the avatar seen on the screen follows the moves made by the player, participants appeared to be more aware of how the games work and provided more feedback. The game theme was positively commented as it concerned an environment familiar to most end users.

The participants seem to have liked the game “harvesting olive trees”. However, there were some concerns about how the crops would appear on the trees and how they could organize their harvest.

There were positive comments regarding the combination of colors and how the scenery generally looked in the game scenarios. One end user commented that it would be better for the buttons to

appear with more shade around their outline to indicate clearly that this is an interaction button.

As it was conveyed that the games will be enriched with musical themes, participants wondered about the genre of music and the sounds that will be used in the games. Participants were informed that the goal is to include sounds that are natural to the environment. It was suggested that music should be rhythmic to give the right tone for physical activities.

Most participants expressed concerns about the familiarity of older people with the use of technology and the use of related applications. In particular, for the game applications and for the first sessions of the intervention, they suggested that clear instructions should be given for the execution of the movements using an avatar-guide or a video. They also suggested using a permanent “Show me the move” button that could be used at any time by the end users when they need help. A relative view that was expressed indicated that such game applications could also be used as an incentive to familiarize older people with the technology in general.

With respect to the distinct game difficulty levels and the required movements, participants agreed that in-game exercise programs should have a variation from very simple for the weakest participants and gradually evolve for the most competent. There was a difficulty in understanding this function at first. There was a concern that they might be forced into activities that are difficult and that will not be able to cope with them. The explanation given that the game will automatically adjust the difficulty of the game according to the player’s abilities and that the player will be able to adjust the choice of difficulty helped to better understand this platform functionality.

Experts alike end users suggested multiplayer support, preferably in a collaborative form rather than competitive. Given that such games could be used in daily care centers for elderly, a physiotherapist could work with groups of 3-4 people at the same time, an option that provides opportunities to enhance elderly socialization beyond other factors, i.e., motor and cognitive functions.

The end users in their majority agreed that most of the movements that are requested in the exergames shown to them seem feasible albeit some may be more challenging (e.g. ‘standing on one leg with arm lifting’), that the exercises seem realistic relatively to the flow of the games, that these games could be used for the intended purpose, and that they have understood most of the information on the screens of the prototypes presented.

The exercises integrated in the game scenarios were assessed for suitability by experts in orthopedics and physiotherapy with positive feedback. According to their evaluation the exercises selected support the kinetic dimension of the program and can help the elderly to reinforce their balance and strength and as a consequence to prevent osteopenia and to reduce vulnerabilities and fall risk.

The experts also expressed their concern about the suitability of the games for people with low mobility. The approach that can be followed in this respect is to integrate into the exergames more movements in the sitting position. From a technical point of view, this requires training of motion recognition algorithms for both standing and sitting positions.

Finally, the idea of accessing additional games at a small cost was discussed. This approach was thought to have a positive effect on continuing the exercises for a longer period of time as one can get tired of playing the same game all the time. Although participants agreed that the idea is useful they showed reluctance to pay the cost themselves and wondered whether their insurance fund could cover it.

4.4 Aspects of Attention

Older people have some characteristics that need to be taken into account when developing technological systems for them. These characteristics can be summarized as follows:

- Impairment of cognitive functions such as memory weakening and reduced ability to learn new things.
- Impairment of sensory functions, such as reduced visual and hearing acuity.
- Intensity of health problems with older age.
- Mobility deterioration.
- Different needs and requirements depending on their lifestyle and cultural, social and economic background.
- Need to use auxiliary equipment, for example using a walker device when standing and walking.
- Little or no familiarity with technology and therefore a lack of trust in technology systems. Trust improves when successful interaction with specially designed systems happens.
- Difficulty in retaining and recalling much information, suggesting that it is important to take into account memory-related issues.
- Response difficulty to more than one task simultaneously.

The overall analysis of the data collected during the FG workshop raises some key issues that should

be taken into account in the implementation of the games. These elements are summarized in Table 2.

Table 2: Aspects requiring attention in the design/implementation of games.

Aspect	Design Guideline
Game theme	Daily life activities: excursions in nature, vacation, swimming, fishing, life on a farm, gardening, sports, dancing, puzzle games, home tasks, shopping at the supermarket.
People diversity	The game should take into account the diversity of people (gender, age, educational attainment, social/cultural background), e.g. in the avatar selection
Dual activity	Exercises combining physical movements and cognitive skills training
Instructions	What is expected by the player, why the player has to do the exercise and what is the benefit that will arise? How will the player carry out various activities, challenges and exercises?
Feedback	Whether movements are done correctly Positive and motivating
User interface	Easy and intuitive menu Easy navigation Clearly visible objects Limited number of information and elements
Motivation	Enjoyment Clear objectives that can be achieved
Progress	Allow progress in the game to enhance the player's self-effectiveness and self-esteem
Multiple levels	Different levels of difficulty, where additional challenges can be added to higher levels
Social interaction	Multiplayer games or use of games in daily care centers for elderly people
Music and sounds	Appropriate music: rhythmic music, classical music, no music, natural sounds (air, birds, water flowing)
Adaptation of difficulty	Adjust the rate of difficulty change in the game according to the user's profile and performance
Usage statistics	Ability to store user's progress and results for later analysis

5 CONCLUSIONS

Physical activity is important for the elderly to preserve good health and quality of life. In order to encourage the elderly to be more physically active, they should be provided with easy to use applications that will actually motivate them to perform helpful exercises for long periods. In GAME2AWE, the goal is to create friendly exergames for the elderly using multiple enabling technologies. The research hypothesis to explore by the end of the project is that by using this platform to exercise physical and cognitive functions systematically, the risk of falling can be reduced and relevant functional indexes would be improved. Such results can have a positive impact on reducing the related social and financial burdens.

In this paper the methodology that frames the development of the platform was outlined and the participatory design of the exergames was explored thoroughly. Qualitative research methods were applied in order to be able to understand end users and the challenges to motivate older people into adopting exergames involving physical activity. The analysis of the data collected raised important issues related to the development of exergames for the elderly and were listed as a set of design instructions to be followed in the development of the platform.

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