Exergame Design Guidelines for Enhancing Elderly's Physical and Social Activities

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***Abstract*—Games based on full-body interaction are able to increase physical and social activity and thus have been evaluated regarding their appropriateness for elderly. Results show that exergames have a positive impact on elderly people, because they help them to remain active and thereby they also contribute to their overall well-being and increased mobility, but most of the existing games on the market are not suitable for them. This work presents design guidelines for the development of exergames which are controlled by body movements and especially considers the requirements of elderly players. Furthermore, these theoretical guidelines are applied to the game FishCatcher, being introduced in this work. Finally, challenges in applying theoretical guidelines to practical games are discussed using the example of FishCatcher.**

***Keywords*—exergame; elderly; physical activities; social activities;**

I. INTRODUCTION

Exergames are computer and video games which are not played sitting in front of the computer or any other monitor, but require full-body movement of the player to control the game [1]. Various input devices for exergames exist, for example exercise bikes, foot operated pads and motion sensors [2]. Two different types of motion input can be distinguished. The first uses a controller for tracking the movements of the player, for example the Nintendo Wii Remote [3]. The player has to move the controller or press buttons which are placed on the controller, or even both at the same time. The second type of motion input does not need any controller, but the games are controlled directly by tracking body movements such as hand gestures. Amongst others, Sony PlayStation II EyeToy [4] and Microsoft Kinect [5] belong to this type of motion sensors. Games using these motion sensors have the advantages that players do not have to pay attention to any controller in their hand, but are able to interact with the game directly, thus resulting in a more simple interaction [6].

Exergames are not only used among children, teenagers and young adults, but they can also be used by grownups and elderly to increase physical activity and motivate elderly to be more active (e.g., [7], [8]). Hence, in the field of Ambient Assisted Living (AAL), exergames offer benefits for elderly and enable them to stay physically fit and thus increase the mobility of elderly. In addition, exergames are also applied to rehabilitation to raise the motivation, since exercises with a high number of repetitions are demanded [7]. Furthermore, elderly people lack in staying physically active [8]. Hence, it is important to boost their physical activity in an entertaining way. The development of systems to improve the quality of life and the well-being of seniors to prevent them from age-related diseases and injuries became more significant [9]. Digital games which are not only designed for entertainment, but for education, training, advertising, research or health as a primary purpose, are called "serious games" [10].

Already during the 1980s, Weisman [11] investigated the benefits of using computer games for elderly people. Those games are exercises to improve the eye - hand coordination as well as memory trainings and they can enhance their self-esteem. Weisman evaluates four computer games that are suitable for elderly people, which means they do not depend on quick hand-eye coordination or speed and have no small moving objects. Since no appropriate commercial games were available, adjustments for the needs of elderly are introduced. Evaluation of the adoptions are performed with residents of a nursing home. 80% of those who were invited were willing to play and demonstrated that also elderly people can have fun playing computer games. Weisman highlights the importance of large symbols, clear auditory clues and the adaptability to the users' skills in computer games for elderly people.

After the Nintendo Wii has been introduced to the market, research on the use and benefits for elderly people is conducted. Wollersheim et al. [1] tested the physical and psychosocial effects of Nintendo Wii Sports games among older women. The result of this study shows particularly the social benefits the game-play has on elderly women. They are better connected among themselves, but also to their grandchildren. Furthermore, the study of Clark and Kraemer [12] is based on the Nintendo Wii, evaluating the change in the risk of falling amongst elderly people playing the Nintendo Wii bowling simulation. After two weeks of playing the bowling game on a regular basis, a decreased fall risk of the patient could be shown. Additionally, Harley et al. [13] organized a Wii Bowling League between residents of different sheltered houses to investigate the impact of Nintendo Wii playing on physical and social activities of elderly people. Therefore, regular playing sessions in small groups of residents of close sheltered houses were arranged together with two public events. The study followed the participants over the first year. At the beginning of the study the players encountered problems with pressing the right button in the proper moment. All of them were focused on the game and while one was using the Wii Remote, the others were watching and giving advices. One year later, this complete concentration on the game was gone. Spending time together was more important than the actual game. The players were talking about everyday problems, eating and drinking besides playing the bowling game. The study shows that the Nintendo Wii promotes physical and social activity. But not only the Nintendo Wii is used for investigating the influence of video games on elderly. Beside one Nintendo Wii game, Shubert [14] tested two other video games for their appropriateness as physical activity for elderly people: Dancetown Fitness System and Sony Playstation II

 ISBN: 978-1-61208-309-4

EyeToy. The results show that those two games are more suited for elderly people since they are easy to use and consider the seniors' requirements. The Nintendo Wii games are typically set up by activity directors, not by the patients themselves. Furthermore, they require too fast movements or contain fast moving objects and the feedback is too negative.

Studies have shown that elderly people enjoy the Nintendo Wii bowling game [13], [15]. However, attention should be paid to their sparse experience with computers. Because of the uncertainty about the handling of new technologies, seniors take up a critical stance towards them and are afraid of making a mistake [15]. In the study of Weisman [11], 20% of the elderly who were invited to play computer games refused to do so because they were afraid of exposing their deficits, another 10% needed encouragement. Furthermore, the participants of the Nintendo Wii bowling events of Neufeldt [15] thought they broke the game, when they pressed a wrong button and an unexpected menu was opened. Beside the Nintendo Wii bowling game, other games (e.g., Dancetown Fitness System [14], SilverBalance [16]) exist which are accessible for the elderly people, but several studies have shown that most of those computer games which are already commercially available on the market are not suited for elderly people [14], [17]. Thus, games which are attractive to a senior audience should be developed. Game developers have to be careful not to think about their interests when creating the game, but the needs and requirements of the target group of these games [18].

Another controller for Nintendo Wii games, besides the Wii Remote, which also initiated a lot of new studies related to the use of video games for elderly people, is the Nintendo Wii BalanceBoard. Gerling et al. [19] conducted a study making use of both, the Nintendo Wii Balance Board and the Wii Remote for game control. It is evaluated how age-related changes, especially cognitive and physical limitations, influence game design for elderly people. The result shows that also elderly enjoy Wii games as leisure activity. Gerling et al. [17] investigated the usability and accessibility of two video games which are controlled with a Nintendo Wii Balance Board for elderly players. The game with a reduced graphical style and the possibility of sitting down during gaming is more appealing for elderly people than the other one. Players perceive better game control and are less afraid while using the board since the simpler user interface increases the focus on body movements and the perceived safety in bodily exertion on the balance board. Based on a case study which uses the Nintendo Wii Balance Board to encourage elderly players to the use of video games, Gerling et al. [16] discusses game design guidelines for developing safe and usable games for elderly people. The major guidelines, which are mentioned in this paper, are: elderly people should be able to play sitting and standing, no extensive or sudden movements should be required, players should be able to adjust the level of difficulty individually and the game should give constructive feedback to avoid frustration. The Nintendo Wii BalenceBoard is also used by Navarro [9], who conducted a study concerning the usage of interactive games to improve the physical and mental well-being of elderly. Therefore, four Nintendo Wii balance games are analyzed. As a result, a design framework is proposed, which contains the following feedback loop: (1) monitoring the current status of the patient, (2) interpretation of this data, (3) adjustments of the trainings plan (if needed), (4) communication back to the patient and (5) repetition of this cycle.

With the launch of Microsoft Kinect, a new technology is investigated regarding its use for elderly people and a new type of gaming concept was introduced. Gerling et al. [6] created guidelines for full-body interaction in games for elderly people. Therefore, they conducted two studies; the first one investigates the performance of a given set of gestures. The results show that traditional gesture movements should be limited for elderly people. Based on those findings, a game was implemented using a Microsoft Kinect for gesture recognition and is evaluated during the second study. It is shown that this game, which uses gestures that are suited for elderly people, has a positive effect on the participants' mood. Borghese et al. [20] developed a low-cost system which can be used for at-home rehabilitation. The goal is to use technologies such as a Microsoft Kinect and a game engine, which contains two mini games, adapts the game level automatically to the patient's status and gives audio-visual feedback, to motivate the patients to exercise. The whole rehabilitation process can be monitored by the hospital. The aim is to build a game which is enjoyable and at the same time useful for therapeutic purposes.

The aim of this paper is to summarize and evaluate design guidelines based on previous studies to be considered in order to develop a multi-player exergame for elderly people, enhancing their physical and social activities. Furthermore, a prototype of the game FishCatcher is implemented according to these guidelines and results are discussed. The rest of this work is structured as follows: design guidelines for exergames are summarized in Section 2, their implementation on an elderly friendly game is shown in Section 3. A discussion of the application of these guidelines and a conclusion is presented in Section 4.

II. Design Guidelines for Exergames

As previous studies have shown (e.g., [14], [17]), already commercially available games on the market are not suitable for elderly people. Evaluation of digital games led to guidelines helping to create an appropriate game for the senior audience. These guidelines evolved from testing and analyzing commercially available games, research studies as well as discussions with elderly people [18]. This section summarizes those guidelines and provides the basis for the implementation of FishCatcher.

1) Mind the physical condition: An important factor to be considered when designing a video game for elderly players based on body movement are the age-related processes, having an impact on the ability to move [6]. Common age-related changes are decrements in posture, balance, gait and fine motor skills, affects on visual and hearing senses as well as impairment of short-term memory, attention and vigilance [19]. Additional aspects to be addressed are longer reaction and overall movement times and the increased risk of fall. Especially the latter has to be respected to avoid unsuitable movements which cause injuries [6].

Due to diseases or injuries of the elderly players, limited use of the extremities and the presence of wheelchairs have to be accounted for. This can be realized by offering gestures

 ISBN: 978-1-61208-309-4

where the user can either use one arm or both and can be carried out standing or sitting. The range of motion should be evaluated according to the abilities of each individual player. Instead of a high precision of gesture recognition, a bigger tolerance should be claimed. To avoid overexertion and injury, the player should have enough time to relax and recover between physically intense periods [6].

2) Use appropriate gestures: Players should have the possibility to learn the gestures before the actual start of the game in a tutorial [6]. They should become familiar with the technology during training phases. As soon as those trainings are not required anymore, players should be able to skip them [9]. It should not be assumed that players remember different gestures over the whole game period, especially that they can recall the gestures in the moment they are required. This means it should not be necessary that the player performs a gesture to trigger another action, but there should be an in-game event which reminds the player to perform the gesture [6].

3) Avoid small objects: Most existing games, which are currently available on the market, are not suitable for elderly people because they consist of small, fast moving characters and targets which can produce strain and anxiety [11], [20]. It is easier for the elderly to have just one task at the time to deal with and also to play with bigger characters.

4) Give visual and auditive feedback: Unlike young people (so called "digital natives"), elderly people did not grow up surrounded by computers and video games. Thus, elderly people are not as confident in their ability to use this technologies as the young [21], which causes computer anxiety. To avoid the anxiety, the players should be encouraged by positive feedback and successful experiences. Therefore, it is recommended to give positive feedback on learning goals rather than performance goals.

Players should be able to understand the relation between their movements and the display and the game has to respond according to their movements [9]. They should get feedback so they can learn how to interact with the game. In the case of failure, they blame themselves and not the game, which can lead to a low self-esteem and frustration [17]. As soon as the players finish their tasks or achieve a goal, they should get a positive feedback immediately. They should never get any negative feedback, neither for not achieving a goal nor for not performing an activity [8]. For example, in the project UbiFit Garden [22] the more the player exercises the more beautiful the garden becomes; flowers grow and butterflies appear. If the player does not exercise, nothing happens. There are no flowers growing, but the player does not get any negative feedback.

5) Adjust the difficulty: The goal of the game has to be reachable for the players, so that they keep their motivation and continue playing [9]. Unnecessary cognitive complexity and complex movements should be avoided. Since there is a large range in ability between elderly people, the game should offer the possibility to adjust the difficulty [6]. It is important that more active players are challenged, so that they do not lose their interest in the game and others are not overstrained. The game should not be frustrating, but entertaining [9]. The best way to realize this is to adapt the challenges dynamically. The players should reach a "flow state", in which a good balance between challenge and the players' skill level exist [20]. In this state, they are completely focused on the game which might reduce physical pain or hide possible impairments.

For additional motivation it might be helpful to display the users' previous scores. To become better and beat themselves is an extra personal goal for the players [8].

To keep the game interesting and avoid habituation, especially when playing it regularly, it should contain randomized elements, so that the player has to react slightly different each time [20].

6) Use a clear user interface: Elderly people have no experiences with computer games [6]. To avoid people needing assistance during the game, all instructions should be clear and use common language. Furthermore, no information that is not needed should be included, e.g., additional Graphical User Interface (GUI) elements. All actions should be explained using diagrams or simple on-screen demonstrations. Also, the start-up and shutdown have to be easy, so that neither the older adults nor the nursing stuff need to have specific technical knowledge. The user interface should be easy to use, so that players can focus on the actual exercise [8].

Rules and instructions should also be available as audio [9]. For non-speech audio signals, lower frequencies should be used, since aging might reduce the sensitivity for pure tones and high frequencies [21]. It should be noted that massive in-game sound, in combination with hints and explanations from the assistance or other players, can create stress for the players and result in less fun playing the game [15].

7) Use a suitable topic: The topic of the video game should be adjusted to the interests of elderly people [9]. The participants of the study of [17] made positive comments about the theme of the game, which was related to garden and animals. The entry into the video game world is easier, when the required gestures are related to real-world actions. Seniors prefer games which give them an educational or cultural benefit [18], but they refuse violence in computer games [23].

8) Encourage social interaction: Due to physical disability or other age-related problems, elderly experience social isolation [24]. Video games are one possibility to maintain the relationships with families or friends. Social interaction is an important factor regarding the motivation of elderly people for playing video games [21]. Playing with others who are encouraging and cheering increases the fun [11]. If elderly people start regularly common playing sessions, their social interaction grows. While at the first sessions the main focus is on the game, soon the concentration is shifted to conversations about the game and also about everyday problems. The communication is not only part of the game events, but may also spread into their daily life, for example the playing sessions become a topic of conversation at lunch [15], [13]. Thus, they become closer and get to know each other better [1]. Playing video games does not only encourage the social interaction among elderly people, but also improves the relationship to their grandchildren due to the shared interest and new topic of conversation. Elderly people are pleased to have the feeling to be up to date with their grandchildren and be able to play with them at a later date [13]. The design of a game and its interface which addresses both the older generation and their grandchildren at the same time is an interesting challenge [21]. In the study of [18] elderly people

 ISBN: 978-1-61208-309-4

were involved in the design process of computer games. Six out of ten participants designed a multi-player game. Therefore, it is reasonable to design a game that can be played together with others.

III. Implementation of Guidelines: FishCatcher

FishCatcher is an exergame which is implemented according to design guidelines for video games for elderly. In contrast to commercially available games, this game considers the requirements of elderly. Elderly people can benefit from exergames in different ways. First, digital games are a leisure activity. They can be used for relaxation and entertainment. If the game has an accessible design and thoughtfully integrated feedback, it can increase the self-efficacy. Secondly, elderly people can enjoy playing digital games together with others which increases social inclusion and reduces isolation. Not only multi-player games, but also games, which can be played alone, are used as social activity with friends or family. Third, since exergames demand body movements to control them, they help to be physically active [21]. FishCatcher is controlled by arm movements, which are tracked by a 3D sensor (e.g., Microsoft Kinect) and uses the OpenNI library. Arms are tracked using the OpenNI library NITE and tracking is initialized by performing a wave gesture. Visualization of the fish and the surroundings is implemented using OpenGL and blender models.

In this game, yellow and red fish are swimming from left to right and vice versa (see Figure 1). Elderly have to wave with their hands in order for the sensor to recognize them. When this happens, a worm is displayed in front of the hand, in order to directly give feedback about the player's hand position. To catch the fish, the players have to touch them with their hands. If a fish is touched, it disappears and a sound is played, depending on whether a yellow or red fish was touched. Hitting red fish results in a deduction of two points, whereas each yellow fish that was caught yields one point. At no time the score can become negative, in order to avoid negative feedback. The score is represented by stars, where one star corresponds to one point. When a player has collected ten points, a big star is displayed instead of ten smaller ones. The game stores the best five scores and displays them on the menu, so that the players can see their improvement.

One game lasts 30 seconds, and, during this time, the players try to catch as many yellow fish as possible, while avoiding touching the red fish. The remaining time is shown by a small yellow fish at the bottom of the window. When the game starts the fish is located leftmost at the bottom. During the 30 seconds, this fish moves to the right side. After that time, the fish is located rightmost, which signifies that the game is over. After one game is over the users can take a break and decide whether they want to continue playing or not. Furthermore, the player can choose between three different levels of difficulty. The easiest one contains the fewest amount of yellow fish and also of red ones, while the most difficult level consists of the biggest number of yellow and red fish, respectively. Another difference between those three levels is the velocity and the size of the fish. The fish in the simplest level are swimming slower and are bigger than the fish of the most complex level. In the medium level, the numbers of fish, the velocity as well as their size are in between the two others.

Fig. 1. Yellow and red fish are swimming, the stars specify the current score and the little fish at the bottom shows the remaining time

A. Game Modes

The game offers different variants of playing. In addition to the previously described way, the single-player mode, two possibilities of multi-player modes exist, which are described in the following section.

- Single-Player: This way of playing is already described in the previous part. One player tries to catch as many yellow fish as possible while avoiding to touch the red ones. The goal is to receive as many points as possible.
- Multi-Player 1: This variant is similar to the previous one. In contrast to the previous version, in this mode two or more players are catching together the yellow fish. The number of caught yellow fish of both players is added together.
- Multi-Player 2: Also for this mode at least two players are required. One or more players catch all the yellow fish, while the other one(s) catch the red ones. If the score is zero at the end of the game, the players who caught the red fish won; if it is greater than zero, the other players won.

The game FishCatcher, as well as games which were introduced in previous studies, is controlled by hand movements. One reason for using only hand gestures is the high number of elderly people who are unsteady on their feet or sitting in a wheelchair. Since games which are really controlled by full-body movements might increase the risk of falling of those people, it is reasonable when the game can be controlled by hand gestures only and thus be played also sitting. Furthermore, to train arms and hands is also important for daily activities, such as grasping objects or brushing teeth. With exergames, elderly people are not only encouraged to move their arms, but also their coordination capabilities (especially hand - eye coordination) are improved.

B. Exergames Design Guidelines Applied On FishCatcher

Before the start of the development of FishCatcher, studies regarding guidelines, especially in the context of games for elderly and exergames, were analyzed. This section illustrates the integration of those guidelines in the game FishCatcher.

 ISBN: 978-1-61208-309-4

1) Mind the physical condition: An important issue is to consider the physical condition of elderly, since age-related processes may have an impact on the ability to move. FishCatcher is developed to address as many elderly as possible. Therefore, it is created in such a way, that the players can stand on their feet as well as sit on a chair or in a wheel chair while playing the game. In addition, it can be played using both arms as well as just one of them. Since the fish are swimming from left to right and vice versa, different positions to catch a fish exist. This means that no unsuitable movements are required because each player can decide individually which position is the most pleasant one to touch the fish.

2) Use appropriate gestures: It should not be required that the players have to perform a gesture to trigger another action. In FishCatcher this is avoided, since the fish only have to be touched and no gestures are required.

3) Avoid small objects: Although the size and the velocity of the fish are depending on the chosen level, even for the most difficult level the objects were designed to fulfill the criterion of not being too small or moving too fast.

4) Give visual and auditive feedback: Since it is recommended to provide not only visual but also auditive feedback, a sound is played after a fish was caught and disappeared. The sound is different for red and yellow fish, so that it is possible to use audio in order to be able to differentiate between yellow and red fish. To give positive feedback when users manage to catch a yellow fish, they get a star, which symbolizes one point. Although the players lose points when they touch red fish, they do not get a real penalty since the points never become negative. The worm which is displayed on the hand gives the user the feedback that the hand was recognized by the sensor. If no worm is visible, the hand was not recognized and the user can not catch the fish until the waving gesture is performed so that the sensor recognizes the hand again. Hence, the users are able to understand the relation between their hand movements and the display better.

5) Adjust the difficulty: To be adaptable for different players, no matter if they are active or frail, they can choose one of three levels each time a new game is started. The more active players should be challenged with the difficult level, and the frail ones should not be overstrained with the easy one. To give additional motivation, the best five scores of previous games are displayed. This shows the users if they are getting better after repeating the game several times. To avoid exactly the same movements for each repetition of the game, the size and the velocity of the fish contain random values. Thus, players have to react slightly different each time.

6) Use a clear user interface: The user interface of the game is quite simple so that it is not overloaded with unnecessary elements and the user is able to concentrate on the game. While the game is loaded, an instruction for the game is displayed. On the menu screen, a short description and a simple animation show the players how to move their arms in way that the sensor can recognize them. The current score of the game is not shown as a number, but as stars. To avoid having too many stars displayed at the same time, always ten stars are collected as one big star.

7) Use a suitable topic: To adjust the topic to the interests of elderly people, who prefer games regarding garden and animals, fish were chosen as the theme of the game.

8) Encourage social interaction: FishCatcher encourages social interaction, since it is also suitable for several people playing at the same time. One possibility is the first multi-player mode where two people try together to catch as many yellow fish as possible. Each of the persons can play with either one or two hands. They can play both standing, both sitting or even one standing and one sitting. The alternative is to play the second multi-player mode, where one player tries to catch as many yellow fish as possible, while the other player catches the red ones. Also for this mode the players can choose to use one or two hands and to sit down or stand up individually. It is even possible to have three or four users playing at the same time if each of them uses just one hand, but thereby may arise the difficulty to place all the people in front of the sensor.

IV. DISCUSSION

This section discusses the implementation and application of the guidelines on the game FishCatcher as well as provides feedback and experiences gathered playing the game. At the beginning, it should be mentioned that by simply considering eight guidelines, the developed game is not necessarily accepted by the end-user automatically since all guidelines offer freedom of interpretation. Furthermore, these guidelines summarize general requirements when developing games for elderly, but do not take personal requirements and constraints into consideration. Hence, it is necessary to consider these additional constraints when developing games. However, the guidelines presented in this paper are the most important guidelines to be considered in any case to address basic requirements. Figure 2 shows an elderly playing the game and providing feedback. In order to use a suitable topic for the developed game, fish were chosen as topic since they are well known. To avoid difficult and complex gestures, fish are caught by touching them. However, this does not reflect the usual way of catching fish (i.e., by fishing) and thus might be confusing for the elderly. A preliminary test has shown, that only touching the fish to catch them might be even too simple since one elderly tried to wipe over the fish in order to catch it. Hence, simplicity is important but a trade-off for the mapping to real-life applications needs to be found.

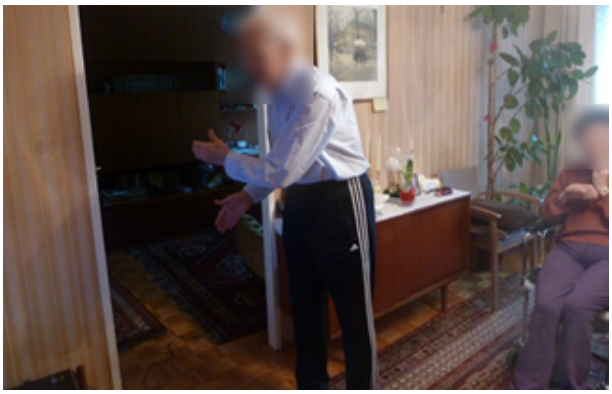

Fig. 2. One person is playing the game during preliminary testing of FishCatcher

 ISBN: 978-1-61208-309-4

Negative feedback is avoided by the fact that the total score can not be negative. However, touching red fish does result in the loss of points in order to increase the level of difficulty. Since this is needed in order to ensure a minimum level of difficulty and avoid elderly getting bored, this might also have an negative consequence since it can be seen as form of penalty, which should be avoided.

Preliminary test results also indicated that the waving gesture at the beginning to initialize the hand tracker is too complex and might overstrain elderly. This is especially the case if the tracker looses the track of the hand and re-initialization is needed during the game. To re-initialize the hand-tracking the waving gesture needs to be perforemed. If this initialization is needed during the game, no information on how to initalize the game is displayed. This will be improved in the next version of FishCatcher. Moreover, the possibility of using either one or both hands changes the level of difficulty, since it is more challenging not only to catch the yellow fish but also to avoid touching the red fish when playing with two hands simultaneously. Playing the game with two hands enhances the hand-eye coordination, since not only one hand but two hands need to be coordinated at the same time. However, depending on the personal constraints when playing the game, this can either act in a motivating or overstraining manner.

V. Conclusion and Future Work

Playing exergames allows elderly to remain active and socially integrated. This paper presented important guidelines to be considered when developing exergames fitting the specific requirements of elderly people and thus enable them to stay physically and socially active. Following these guidelines does not necessarily ensure that elderly are accepting the game, but ensures to satisfy their basic needs. The game FishCatcher following these guidelines was developed and the application of the guidelines to this game was discussed. Future work deals with an evaluation of FishCatcher and gathers feedback from the end-users in order to verify the feasability of the proposed guidelines.

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 ISBN: 978-1-61208-309-4