Exergaming for Elderly: Analyzing Player Experience and Performance

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Abstract

Although research results suggest that playing physically exerting games has a positive impact on senior citizens' overall well-being, commercially available products are rarely designed with senior users in mind. In this paper, we present an evaluation including Nintendo Wii Fit balance games and our own interaction prototype *SilverBalance* aimed to examine the accessibility and overall feasibility of the Nintendo Balance Board as input device among elderly players. In this context, we compared the gaming performance of active senior citizens and members of a full-care nursing home who require extensive care and are dependent on assistive devices when walking. While the results show that age-related impairments do have an impact on the use of video games among frail elderly in terms of player performance, they also suggest that the individual enjoyment of engaging in games is not affected by age and may therefore represent a promising opportunity for future game design efforts.

1 Introduction

Recent results of case studies exploring the use of digital games among elderly persons suggest a variety of positive effects on the well-being of senior citizens (Jung et al. 2009; Pigford 2010; Rosenberg et al. 2010). Yet, only few games are designed for the growing target audience of persons aged 50 and older, and it is suggested that many commercially available entertainment systems are not suitable for frail elderly (Gerling et al. 2010; Gerling & Masuch 2011). This is especially important in the context of exertion game design: Age-related changes such as cognitive impairments, decrements in motor skills as well as posture and balance and the impact of chronic diseases severely influences the use of digital games among senior citizens (Birren & Schaie 2011; Czaja & Lee 2008; Gamberini et al. 2006) and may be problematic in terms of engaging with physically challenging games.

Wii Fit, the release title for the Wii balance board (Nintendo 2010), features numerous yoga and muscle workouts and a variety of mini games such as skiing, snowboarding or rope walking which aim to improve the player's balance. Preliminary research results suggest that engaging with Wii Fit and similar games may positively influence the well-being of elderly persons (Rosenberg et al. 2010), but also mention certain negative aspects regarding usability and accessibility such as the risk of injury or general game design issues (Hanneton & Varenne 2009; Pigford 2010). However, because available research strongly focuses on user experience and emotional well-being, little data exploring the accessibility of exertion games among elderly players is available.

In this paper, we aim to examine the suitability of commercially available exergames using the example of Wii Fit. The focus of the study lies on adult players, particularly examining differences between active and frail elderly persons. Furthermore, the accessibility and usability of Wii Fit is compared to the research tool *SilverBalance*, which was developed based on design considerations for the design of exertion games addressing frail elderly.

2 Related Work

The issue of game development for elderly persons has been addressed by previous academic work. During the 1980s, Weisman (1983) examined the use of digital games among institutionalized elderly and suggests the implementation of clear visuals and generally adjustable games for elderly audiences. This idea is supported by Ijsselsteijn et al. (2007), who recommend the creation of visually adjustable games which provide multimodal feedback. Additionally, Flores et al. (2008) have addressed the design of games for rehabilitation and highlight the importance of therapy-appropriate interaction paradigms as well as adequate cognitive challenges. Besides addressing the design of usable and accessible game mechanics, De Schutter and Vanden Abeele (2008) highlight the importance of meaningful play among elderly audiences, who are strongly interested in benefitting from play on a personal level, e.g. by educating themselves instead of engaging in play for mere entertainment. Additionally, research has examined the acceptance of digital games among senior citizens as well as the impact of playing games on elderly persons. Preliminary results of gaming sessions in nursing homes report a general interest in engaging with digital games (Ulbrecht et al. 2010). Furthermore, studies presenting exertion games to elderly persons report positive effects on their overall well-being (Jung et al. 2009) and a reduction of the risk of depression among institutionalized elderly (Rosenberg et al. 2010). Also, commercially available digital games with exertive elements have successfully been applied in physical therapy to reduce the risk of falls (Pigford 2010).

In terms of creating physically exerting games, research has mainly focused on providing design recommendations for younger audiences. Sinclair et al. (2007) present an analysis of commercially available exergames and highlight the importance of enjoyable game elements as motivational factors to foster physical activity among children and teenagers. Mueller and Agamanolis (2007) highlight the potential of exertion games in fighting obesity, providing entertainment software and augmenting regular sport experiences. An approach towards providing adjustable exergames to address individual user needs is presented by Göbel et al. (2010), who implement biofeedback to adjust in-game challenge to the player’s skills. Regarding the design of exertion games for elderly players, little research is available, and first pilot studies rather focus on adult players in general. It is suggested that exertion games for frail elderly players should account for different interaction paradigms allowing the player to engage in play while sitting or standing to account for physical limitations. Furthermore, quick movements should be avoided to reduce the risk of injury, and games should feature an adjustable level of difficulty. Finally, it is recommended to focus on simple interaction mechanisms to account for the lack of gaming experience among the target audience (Gerling et al. 2010).

3 SilverBalance

SilverBalance was designed to assess basic interaction and game design for senior players using the Nintendo Balance Board. The game prototype features two balance tasks and a minimalistic, focused visualization of game play as suggested by previous work (Gerling et al. 2010). Our preliminary focus group test showed that two specific considerations in the design process help to ensure accessibility for an elderly audience:

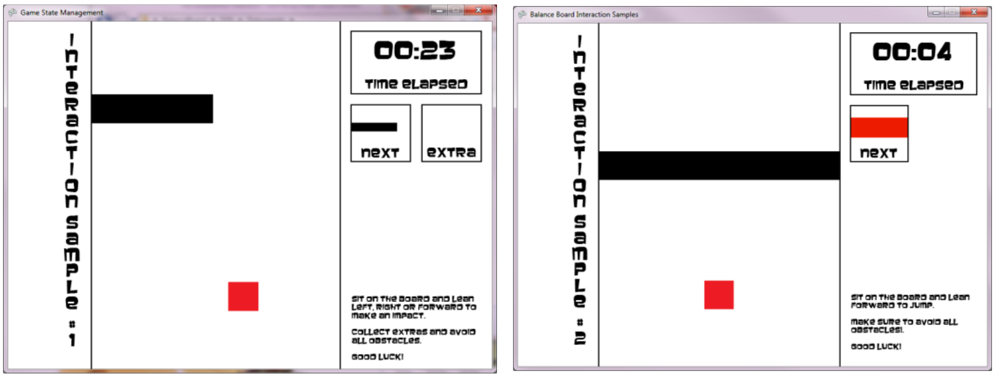

Figure 1: Balance Task #1: Jump, Balance Task #2: Avoid

First, a simplistic design of the graphical user interface accounts for reduced visual and cognitive abilities and allows a user to focus on game play instead of being distracted by animations or other graphical effects. Second, the sensor configuration of *SilverBalance* supports navigation in two positions as players may decide whether they want to engage in play while sitting with their feet placed on the board or standing. Thereby, different physical abilities are accounted for. In the following, we present the two game tasks of *SilverBalance*, Jump and Avoid. The core objective in both tasks is to avoid obstacles through body activity. Once a task is completed, the player receives feedback regarding the individual performance which is quantified through high scores for avoided obstacles and the overall playing time.

3.1 SilverBalance Task #1: Avoid

SilverBalance Task #1 requires the player to avoid obstacles which slowly move from the top of the screen down to the bottom where the red player icon is located (cf. fig. 1). Obstacle alignment to either sides of the screen is random, and each obstacle slowly proceeds to the bottom of the game area during the course of play. The player icon is controlled by executing force on the left or right area of the Balance Board. Additionally, two bonus items are included which affect the player's status for a period of ten seconds. If a yellow bonus is collected, player speed is reduced and the player needs to plan ahead in order to avoid obstacles. If the player picks up a green bonus item, shifting his/her weight to the left will cause the virtual player representation to move to the right and vice versa. Thereby, we try to introduce small cognitive challenges which may be integrated into more complex game mechanics at a later point. The goal of the Avoid-task is to hold on avoiding obstacles as long as possible while their speed continuously increases with every turn.

3.2 SilverBalance Task #2: Jump

In the second balance task, the obstacles stretch across the whole width of the game area and have to be avoided by jumping over them. The player enters the jump state by putting pressure onto the upper area of the Balance Board. It has to be held at a constant pressure level on as long as an obstacle is overlapping with the red player icon. As the obstacles differ in thickness, the player has to sustain pressure for different duration times. The required weight shift is intended to correspond with the induced shift when getting up from a chair, hence we expect players to be familiar with the physical activity required to transition between both game states. Therefore, we try to ease an entry into play for users without prior gaming experience. As with *SilverBalance* Task #1, speed gradually increases during the course of the game until the user fails to avoid collision and the player icon touches an obstacle.

4 Wii Fit

Wii Fit is the release title for the Wii Balance Board designed by Nintendo (2010). The game features numerous yoga and muscle workouts and a variety of mini games such as skiing or rope walking which aim to improve the player's balance.

Wii Fit Balance Games

Based on the aforementioned features of *SilverBalance*, two Wii Fit balance games implementing similar interaction paradigms were selected for further evaluation. Wii Fit slalom skiing offers a downhill skiing track on which different obstacles have to be passed. The interaction paradigm associated with this game mechanic requires the player to shift his weight on the balance board left or right in order to move to the left or to the right and pass obstacles. Furthermore, the player may lean forward to speed up and backwards to slow down. Thus, the interface implementation is comparable to the interaction paradigm introduced in *SilverBalance* task #1. To measure player performance, the total completion time as well as the number of missed obstacles are tracked. Wii Fit ski jumping requires the player to speed up on a jump by leaning forward while squatting down and then to stretch his legs to take a jump. Likewise, *SilverBalance* task #2 offers the player the possibility of putting pressure on the upper sensors of the board by leaning forward, but is not required to squat first. Player performance is measured by providing information on the length of each jump.

Generally speaking, the majority of games features input paradigms closely related to the actions displayed within the game so that the player can simply imitate real movements, e.g. swinging from side to side when skiing or carefully stepping on the rope. While this may be advantageous in terms of intuitive input, we found that a basic requirement of these games is that the player is safely standing on the board and is able to move freely within the radius of an arm's length. This may be problematic for an elderly audience with regards to their physical limitations. Furthermore, some of the games require fast responses at a generally high game pacing. This may lead to quick, uncoordinated reactions with wide shifts of the player's center of gravity. Additionally, previous research results suggest that elderly players quickly immerse in Wii Fit and are easily distracted by the action on the screen (Hanneton & Varenne 2009). Thus, their attention shifts from their movements and safety to in-game action which may further increase the risk of injury.

5 Evaluation

The goal of the evaluation was to collect formal data of seniors from two different age groups regarding three key aspects: The Game Experience Questionnaire (GEQ) (Ijsselsteijn et al.) should give a general first impression on the experience of seniors with exergames. Second, we specifically asked them about safety and usability experiences with the balance board, comparing Wii Fit and *SilverBalance*. Finally, we also collected performance data during play to include objective information regarding the players' achievements.

5.1 Participants and Procedure

The evaluation was realized in two units. First, the game was presented to senior citizens without major impairments in a lab setting (Group 1). Second, the game was tested among members of a full-care nursing home (Group 2). In total, 16 persons participated in the evaluation. The average age within group 1 was 58 (Range: 54 to 65), the average age within group 2 was 82 (Range: 67 to 91). All of the subjects within group 2 suffered from age-related decrements in motor skills and were dependent on assistive devices when walking. None of the participants were avid gamers, or had prior experience playing exergames.

At the beginning of the evaluation, all participants received a short briefing regarding their tasks and the structure of the study. Then they were asked to fill in the first part of the questionnaire which included personal details. Additionally, it was verified that none of the participants suffered from diseases which would put them in danger when participating in exertion games. This step was followed by the first playing session during which the subjects were invited to play Wii Fit slalom skiing (WF_Slalom) and ski jumping (WF_SkiJump). Each game was repeated three times. Afterwards the second part of the questionnaire was answered. Finally, the participants played each *SilverBalance* task (SB_Avoid, SB_Jump) three times and filled in the last part of the questionnaire.

5.2 Game Experience Questionnaire (GEQ)

The GEQ was included in our evaluation in order to gain insight into personal experiences and feelings of the participants regarding their perception of the Wii Fit balance games. It measures seven dimensions aiming to examine the individual user experience, which are each represented by six 5-level Likert-scale items (0 = completely disagree to 4 = absolutely agree). Unfortunately, the group of frail elderly persons was unable to answer this part of the questionnaire due to its length and the impact of age-related decrements. Therefore, the GEQ was only included in the questionnaire for the group of active senior citizens. Thus, only a limited number of subjects (N=9) participated in the more extensive version of the evaluation. Figure 2 shows the results which suggest a positive gaming experience due to the high scores for *positive affect* (M=2.72, SD=0.28) and low values for *negative affect* (M=0.31, SD=0.25) and *tension* (M=0.70, SD=0.95). The remaining values for *challenge* as well as *immersion* and *flow* are at average levels while the level of perceived competence is low (M=1.20, SD=0.27).

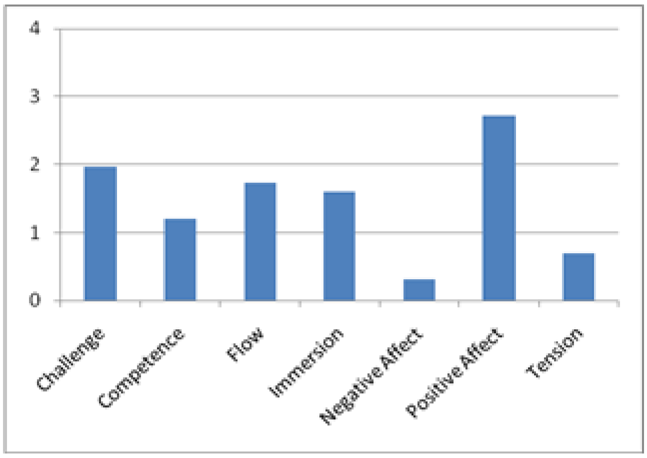

Figure 2: Mean results of the Game Experience Questionnaire (GEQ).

5.3 Quantitative Evaluation

The questionnaire consists of a set of ten 5-level Likert-scale items (0 = completely disagree to 4 = absolutely agree, 2 = neutral) for each of the two games (WF=Wii Fit, SB=*SilverBalance*). Table 1 provides an overview of the questionnaire, table 2 gives the descriptive results in arithmetic mean (*M*), median (*MD*), and standard deviation (*SD*) for each game among the two groups. The small group sizes (N_{Gr1}=9; N_{Gr2}=7) did not allow for assuming normal distributions. We thus applied a non-parametric Mann-Whitney *U* test to analyze significance (exact sig., 2*1-tailed) of these results.

All groups agreed ($MD \geq 3$) on having fun to use the board ($Q1_{WF}$) with both games. The small differences between the groups for Wii Fit and *SilverBalance* (for each MD_{Gr1}=3;

MD_{Gr2}=4) were neither significant for WF (U = 16.0, p = .114) nor for SB (U = 21.0, p = .299). Despite Q1 and Q7, using the balance board with the Wii Fit game (WF-condition) was rated significantly different for all items between the two groups: Group 2 disagrees with unproblematic usage, while group 1 gives a neutral rating ($Q2_{WF}$: $MD_{Gr1} = 2$, $MD_{Gr2} = 1$, $U = 5.0$, $p \leq .01$). Similarly in comparison to group 2, group 1 could more easily keep their balance ($Q3_{WF}$: $MD_{Gr1} = 3$, $MD_{Gr2} = 1$, $U = 10.0$, $p \leq .05$), they rated the design more positively ($Q4_{WF}$: $MD_{Gr1} = 3$, $MD_{Gr2} = 2$, $U = 8.0$, $p \leq .05$). They stated no problems with being afraid to fall off the board ($Q5_{WF}$: $MD_{Gr1} = 0$, $MD_{Gr2} = 3$, $U = 0.0$, $p \leq .01$) and did not require grabbing a hold of something, completely opposed to group 2 ($Q6_{WF}$: $MD_{Gr1} = 0$, $MD_{Gr2} = 4$, $U = 0.0$, $p \leq .01$). Both groups did not see much help given by the board to quickly react to play situations ($Q7_{WF}$: $MD_{Gr1} = 2$, $MD_{Gr2} = 1$, $U = 16.5$, p =.114). Albeit, the difficulty of play was judged indifferently, as only group 2 agreed on having problems with the game speed ($Q8_{WF}$: $MD_{Gr1} = 1$, $MD_{Gr2} = 3$, $U = 7.0$, $p \leq .01$) and with performing movements ($Q9_{WF}$: $MD_{Gr1} = 1$, $MD_{Gr2} = 3$, $U = 7.5$, $p \leq .01$). They also felt less safe while using the board than group 1 ($Q10_{WF}$: $MD_{Gr1} = 3$, $MD_{Gr2} = 1$, $U = 7.0$, $p \leq .01$).

Q1:	It was fun to use the board.
Q2:	Usage of the board was possible without problems at any time.
Q3:	I never lost my balance while using the board.
Q4:	The form and design of the board are optimal for me.
Q5:	I was afraid to tumble or to fall off the board.
Q6:	I required balance support while standing on the board.
Q7:	Thanks to the board, I could quickly react to all play situations.
Q8:	I feel that the game was going too fast for me.
Q9:	Some of the movements were difficult to perform.
Q10:	I felt safe using the board.

Table 1: Questionnaire items.

In comparison to these findings on Wii Fit, both groups only show marginal differences with judging *SilverBalance* using the same board, none of which are statistically significant. The board was fun to use while playing *SilverBalance* ($Q1_{SB}$: $MD_{Gr1} = 3$, $MD_{Gr2} = 4$) and unproblematic to use ($Q2_{SB}$: $MD_{Gr1} = 4$, $MD_{Gr2} = 4$). Both groups reportedly never lost balance ($Q3_{SB}$: $MD_{Gr1} = 4$, $MD_{Gr2} = 4$) and rated the design as rather optimal ($Q4_{SB}$: $MD_{Gr1} = 3$, $MD_{Gr2} = 3$). They were not afraid to tumble ($Q5_{SB}$: $MD_{Gr1} = 0$, $MD_{Gr2} = 0$) and did not require balance support, despite all members of group 2 either using a rollator or a wheelchair ($Q6_{SB}$: $MD_{Gr1} = 0$, $MD_{Gr2} = 1$). The board was regarded as supportive in quickly reacting to the game ($Q7_{SB}$: $MD_{Gr1} = 3$, $MD_{Gr2} = 3$). The game was neither too fast ($Q8_{SB}$: $MD_{Gr1} = 0$, $MD_{Gr2} = 1$) nor were the requested movements too difficult ($Q9_{SB}$: $MD_{Gr1} = 0$, $MD_{Gr2} = 0$). Both groups felt safe while using the board ($Q10_{SB}$: $MD_{Gr1} = 4$, $MD_{Gr2} = 3$).

Looking at the different ratings for the two games within each group, group 1 rates the following items significantly different: $Q2_{G1}$ ($MD_{WF} = 2$, $MD_{SB} = 4$, $U = 18.5$, $p \leq .05$), $Q7_{G1}$ ($MD_{WF} = 2$, $MD_{SB} = 3$, $U = 17.5$, $p \leq .01$), $Q8_{G1}$ ($MD_{WF} = 1$, $MD_{SB} = 0$, $U = 17.0$, $p \leq .05$), and $Q9_{G1}$ ($MD_{WF} = 1$, $MD_{SB} = 0$, $U = 18.5$, $p \leq .05$). Group 2 rates all items despite Q1 significantly different for the two games: $Q2_{G2}$ ($MD_{WF} = 1$, $MD_{SB} = 4$, $U = 0.0$, $p \leq .01$), $Q3_{G2}$

($MD_{\text{WF}} = 1$, $MD_{SB} = 4$, $U = 0.0$, $p \leq .01$) , Q4$_{\text{G2}}$ ($MD_{\text{WF}} = 2$, $MD_{SB} = 3$, $U = 5.0$, $p \leq .05$), Q5$_{\text{G2}}$ ($MD_{\text{WF}} = 3$, $MD_{SB} = 0$, $U = 0.0$, $p \leq .01$), Q6$_{\text{G2}}$ ($MD_{\text{WF}} = 4$, $MD_{SB} = 1$, $U = 0.5$, $p \leq .01$), Q7$_{\text{G2}}$ ($MD_{\text{WF}} = 1$, $MD_{SB} = 3$, $U = 1.5$, $p \leq .01$), Q8$_{\text{G2}}$ ($MD_{\text{WF}} = 3$, $MD_{SB} = 1$, $U = 1.0$, $p \leq .01$), Q9$_{\text{G2}}$ ($MD_{\text{WF}} = 3$, $MD_{SB} = 0$, $U = 0.0$, $p \leq .01$), and Q10$_{\text{G1}}$ ($MD_{\text{WF}} = 1$, $MD_{SB} = 3$, $U = 2.0$, $p \leq .01$).

	WF_Gr1			**WF_Gr2**			**SB_Gr1**			**SB_Gr2**		
	M	**MD**	**SD**	**M**	**MD**	**SD**	**M**	**MD**	**SD**	**M**	**MD**	**SD**
Q1	2.89	3	0.78	3.57	4	0.53	3.22	3	0.83	3.71	4	0.49
Q2	2.67	2	0.87	1.00	1	0.82	3.56	4	0.73	3.57	4	0.53
Q3	2.33	3	1.22	0.86	1	0.69	3.22	4	1.30	3.57	4	0.53
Q4	2.89	3	0.60	1.57	2	0.98	3.33	3	0.50	3.00	3	0.58
Q5	0.00	0	0.00	3.14	3	0.69	0.22	0	0.67	0.00	0	0.00
Q6	0.00	0	0.00	3.71	4	0.76	0.33	0	1.00	0.71	1	0.76
Q7	2.00	2	0.71	1.29	1	0.76	3.33	3	0.71	3.29	3	0.76
Q8	1.67	1	0.87	3.14	3	0.69	0.67	0	0.87	1.29	1	0.49
Q9	1.56	1	1.13	3.29	3	0.76	0.67	0	1.41	0.14	0	0.38
Q10	2.78	3	0.67	1.14	1	1.07	3.44	4	0.73	3.43	3	0.53

Table 2: Descriptive questionnaire results.

For each game, we measured different factors of performance. We asked the participants to perform three trials for each game (Wii Fit and *SilverBalance*). Wii Fit consisted of two tasks, WF_SkiJump and WF_Slalom. We had to drop WF_SkiJump as only two participants of group 2 were able to play the game. Maximum points can be reached by achieving shortest duration times and least missing goals. In WF_Slalom group 1 members in average finished the track in 42.17 sec in average while missing 7.7 goals. Group 2 took 45.17 sec in average and missed 11.2 goals. If we regard group 1 as baseline, group 2 achieves 93% of time performance and 69% in hitting goals. We equally combine these two factors in a total performance of 82% for WF_Slalom. *SilverBalance* also consisted of two tasks: SB_Avoid and SB_Jump. SB_Avoid features the same functionality as WF_Slalom but different objectives: the goal is to play for the longest time without hitting an obstacle plus the number of passed obstacles. In average group 2 (88.76 sec, 15.7 obstacles) shows a combined performance of 47% (52% time, 41% goals) compared to group 1 (169.59 sec, 38.6 obstacles). SB_Jump also takes the maximum duration time without failing to jump and counts the number of passed obstacles. Here group 2 (64.43 sec, 24.7 obstacles) reaches 61% (78% time, 44% obstacles) of group 1 (82.37 sec, 24.6 obstacles).

In summary, we found differences in performance for all games indicating a worse performance of group 2 compared to group 1. The results indicate a larger performance gap between the two groups for *SilverBalance* tasks than for WF_Slalom, although the small number of samples does not allow for a comprehensive statistical comparison. To conclude, such a gap in performance occurs despite given differences in gameplay and balancing between all tasks.

5.4 Discussion of Results

The results of the GEQ indicate a positive game experience with exertion games in general that is affected by a perceived low competence during play. Possible reasons could be a lack of gaming experience and thus a longer learning period, and the necessity to follow one's own movements rather than focusing on on-screen action. The results are only valid for the mobile senior group, as GEQ testing with frail elderly was not possible. An appropriate version of the GEQ for special user groups should be developed in the future. This would allow for multiple testing sessions in order to evaluate Wii Fit and *SilverBalance*.

The questionnaire with questions related to exertion aspects on the Balance Board addressed this issue with both groups. The results show different ratings between the two groups for Wii Fit. In contrast to group 1, group 2 clearly had problems in handling the game. However, both groups were equally positive on SB. Group 1 judged *SilverBalance* to be less problematic to use and indicated a better perceived support through the balance board in mastering game situations. They did not feel overstrained concerning speed and body movements. Group 2 judged all items except for Q1 more positively for *SilverBalance* than for Wii Fit: They felt safer, perceived better game control, and were less afraid while using the board. Regarding the playing performance, both games evoked differences between the groups. In average, group 1 played faster and less error-prone than group 2. In contrast to the more positive perception of playing *SilverBalance* compared to Wii Fit, *SilverBalance* tasks show even more severe differences in performance between the two groups as Wii Fit. In summary, the two groups judge their own efficacy independent of the final performance.

General observations during the evaluation show that elderly players need additional feedback in order to learn how to interact with the game. During the gaming sessions, comments such as "*It is all my fault!*" or "*I am too old and slow to win that game!*" were frequently made by frail elderly players. This suggests that they tend to attribute failure intrinsically rather than blaming the game, which may cause difficulties regarding their perceived self and ultimately affect their perception of digital games. Furthermore, the reduced graphical style and simplicity seem to add to perceived safety in bodily exertion on the balance board. Reduced and structured information onscreen potentially allows for an increased focus on body movements. Also, the results suggest that *SilverBalance* is more accessible to persons who have lost the ability of walking independently as the possibility of sitting down during play facilitates the playing process while the execution of physical input remains possible.

6 Conclusion and Future Work

While active senior citizens may still be able to engage in commercially available exertion games, the evaluation results suggest that differences in mobility and physical abilities affect the use of exertion games among frail elderly persons. In this context, the safety of players is crucial to reduce the risk of injury and to allow seniors to engage in play according to their individual physical ability. Hence, it is necessary to develop games particularly addressing elderly target audiences, as commercially available solutions only partially address this need.

Also, the evaluation results suggest large differences between the performance of active and frail elderly persons. This emphasizes the need for different gaming concepts depending on the agility of the particular target audience instead of merely addressing a 50+ demographic. In this context, further research with a focus on the impact of age-related changes on different structural elements of games should be carried out. Such studies have to overcome certain challenges in evaluating elderly people: Shorter attention spans, the acceptance of repeated measures designs, the adaptability to facility schedules, and addressing a heterogeneous group of seniors with a broad variety of abilities and gaming literacy.

Future work includes the creation of a game concept particularly addressing frail elderly persons. It is planned that the concept optimizes both interaction paradigms and general gameplay for an elderly audience with a focus on physical and cognitive limitations of frail senior citizens living in full-care nursing homes. Furthermore, it is planned to introduce a user-centered design process featuring an elderly focus group to ensure an early adjustment of the game to its target audience and to further explore the possibility of designing physical activity encouraging games for frail elderly players.

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