Motion-Based Game Design for Older Adults

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ABSTRACT
Older adults in nursing homes often lead sedentary lifestyles, which reduces their life expectancy. Full-body motion-control games provide an opportunity for these adults to remain active and engaged; but these games are not designed with age-related impairments in mind, which prevents the games from being leveraged to increase the activity levels of older adults. In this paper, we create a gardening game specifically addressing institutionalized older adults. Additionally, we present an evaluation of the game that demonstrates how full-body motion-control games can accommodate a variety of user abilities, have a positive effect on mood and, by extension, the emotional well-being of older adults, thereby increasing their quality of life.

Keywords
Elderly, games, entertainment, design.

1. INTRODUCTION
Older adults in nursing homes often lead sedentary lifestyles despite physical and cognitive activity being crucial for well-being in old age. Decreased activity adversely affects an individual's life expectancy, frequently leading to *sedentary death syndrome* [15]. Care facilities face the challenge of encouraging their residents to participate in leisure activities. Despite various efforts, few activities remain accessible, and it is difficult to motivate older adults to remain cognitively and physically active as the impact of age-related changes grows (e.g., cognitive impairments or mobility disabilities). Research has shown that playing games can have positive effects on the emotional and physical well-being of elderly persons, and can motivate them to maintain a basic level of activity [3, 12]. The latest generation of game input devices, such as Microsoft Kinect, provides an opportunity for motivating physical activity.

However, commercially available games put older adults at risk of injury by failing to accommodate for their range of abilities. In addition, there are no guidelines for designing gesture-based games for this particular group, and applying traditional HCI guidelines is difficult because games require special consideration to balance the difficulty needed to bring challenge – a necessary component of games – and ease of use. We conducted an evaluation exploring the suitability of full-body motion control for older adults, and we investigated how participants responded to the gestures in our game.

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Results from the study showed the success of our gestures, and demonstrated the positive effect of playing our game on participant mood. Our work contributes a full-body motion-controlled game for older adults and demonstrates that games can have a positive effect on older adults' moods; influencing their well-being and providing enjoyable leisure activities.

As our population ages, and digital entertainment systems become more pervasive, we can expect interest in video games among older adults to increase. Our work can expose the needs of older adults, but can also prepare practitioners to design full-body motion-control games for a broader audience with a range of physical and cognitive abilities.

2. RELATED WORK
Game design for elderly persons has focused on guidelines and case studies. However, motion-based game design has mainly explored the context of younger players.

2.1 Game Design for the Elderly
First considerations on game design for elderly players date back to the 1980s, where Weisman [17] explored the accessibility of Apple II games among institutionalized older adults, highlighting the importance of adaptable games. More than 25 years later, the issue was addressed by Gamberini et al. [8], who focused on the impact of cognitive decrements on the use of entertainment systems, particularly addressing the design of graphical user interfaces. Likewise, IJsselsteijn et al. [11] analyzed age-related changes and present a set of design recommendations including the creation of individually meaningful and visually adjustable games providing multimodal feedback. Considerations of the design of meaningful games [14] highlight the importance of perceived benefits for the elderly. Additionally, Flores et al. [7] address the creation of games for stroke rehabilitation, recommending visual adaptability, therapy-appropriate movements, and suitable cognitive challenges. Different case studies have explored game design for older audiences. To motivate elderly persons to participate in rehabilitation [2], game-based approaches have successfully been used. Often, Nintendo's Balance Board is used as an input device, for example, in various games for balance training [3]. It has also been shown that institutionalized older adults enjoy playing games, but interaction challenges have to be addressed [10].

2.2 Designing Physical Interaction in Games
Physical interaction in video games has been examined from the perspective of providing an exertive sports-like experience, or of exploring gesture-based interaction. Exergames integrate physical activity to engage the player [13]. Much work has focused on creating sports-like experiences to help fight

sedentary lifestyles among younger audiences [13]. High-level considerations regarding exergames for elderly by Aarhus et al. [1] underline the importance of addressing individual differences by allowing players to adjust game speed and complexity. Further research by Gerling et al. [9] addresses the issue of game accessibility for institutionalized older adults by suggesting the support of standing and seated players to account for age-related impairments, and to avoid sudden and extensive movements. However, suitable interaction paradigms are not described.

Given that existing literature has only begun to analyze the needs of older adults specifically in game design, further research on interaction design for institutionalized older adults is necessary. This is particularly important, as effects of age-related changes are likely to affect the suitability of full-body interaction. Additionally, there remains a lack of research on the high-level accessibility of gestures. Interaction paradigms and game mechanics are often granted a higher priority than the consideration of individual player abilities, which is appropriate when designing for younger audiences but may not suffice when designing for older adults. We believe that reversing this philosophy – prioritizing ability before mechanics – makes games accessible to a larger audience.

3. STUDY: GESTURE-BASED GAMING

We created a gesture-based game that invites players to perform movements for growing a flower garden (Figure 1) because prior research suggested gardening themes for games for older adults [14] and gardening themes have successfully been applied in past approaches towards the creation of physical activity motivating games [4]. The gesture system was designed to provide adaptable interaction paradigms that accommodated age-related changes, such as not being able to raise arms over a certain degree or allowing slower steady movements. The game was implemented using the Microsoft Kinect Beta SDK and Game Studio 4.0.

3.1 Game Adjustment and Calibration

Basic information about the player's individual abilities was entered at game start to determine whether seated or standing interaction is possible, and if one-handed play is required. Then, players participated in a short calibration sequence during which they were asked to reach out to small flowers displayed on the screen. First, they were asked to collect as many flowers as possible to evaluate their range of motion (ROM). Second, players had to reach to and hold certain flowers at specific screen positions to determine their strength and their ability of holding a certain pose. Player agility was calculated depending on completion time. Based on these values, players either engaged with the game via static or dynamic gestures. Threshold values for successful gesture completion and effect duration were set accordingly; if a player was assigned a low ROM value, the level of gesture precision was reduced. If players received low values for strength, effects remained active longer to avoid overexertion. Low agility values led to a larger window for gesture completion.

3.2 Gestures and Game Mechanics

We developed four gesture-based game mechanics related to our gardening theme. These mechanics required players to perform different full-body gestures based on their individual abilities.

Growing plants. Players have to stand on one leg (static) or walk in place (dynamic) to grow plants. *Growing flowers.* Players need to lift (static) or wave (dynamic) one arm. This activates rain that spreads from the player's hand onto the foliage. *Making flowers bloom.* Flowers start blooming once players manage to get a certain amount of sunshine by either extending one or both arms to the side (static) or pretending to be flying by waving both arms (dynamic). *Catching the bird.* Once all flowers have grown and are blooming, a bird appears. Players have to move their hand towards it to catch it, which provides an increase in pace.

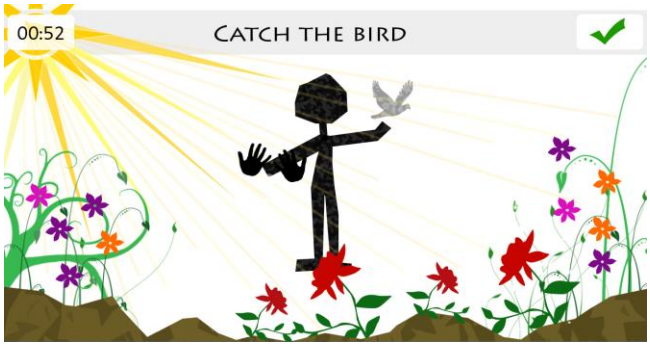

Figure 1. Screenshot of the tutorial phase of the game.

3.3 Instruction and Feedback

The first part of the game provided a period of guided tutorial play in which the game prompted players to perform certain gestures in a predefined order. Players were instructed by short phrases explaining the gesture and a stick figure demonstrating the movement. In the second part players could engage in free play, where they could perform any of the gestures without detailed instruction. When players completed gestures, the gesture was revealed, and players were awarded points. The game used sound to underline the completion of tasks. Once the garden was grown, scores were shown and the game ended.

3.4 Participants and Procedure

Twelve institutionalized older adults (5 female), with an average age of 76.7 (SD=10.6; Range 60 to 91), living in a nursing home participated in our study. Eleven participants were in wheelchairs; only one was able to walk without assistance. Six participants reported having had a stroke, leaving one side of their body paralyzed. The study was conducted in the media-room of a nursing home. Participants first filled out a demographic questionnaire. Before participants started the game, they completed a pre-game PANAS questionnaire [16] to measure their positive and negative affect states. Participants first played the tutorial and then were allowed to engage in free play for five more minutes or until they successfully completed the game. After the session, they completed a post-game PANAS and gave feedback about the gestures and game mechanics.

3.5 Results

Based on the abilities of our study population, static gestures were assigned to all participants, hence we do not study differences between static and dynamic interaction.

3.5.1 Questionnaire Results

Differences in mood as assessed by the PANAS questionnaire before and after playing were analyzed using a paired-samples t-test. There was a significant increase in positive affect after

Table 1. Descriptive statistics for the perceived suitability of the gesture set used for the mini game (5 = completely agree).

Item	Mean	SD
Performing the gestures was fun.	3.08	1.62
Performing the gestures was tiresome.	2.33	1.61
Performing the gestures was easy.	3.83	1.03
Performing the gestures was difficult.	2.75	1.29

playing the game (M=3.88, SD=0.79) compared to before the game (M=3.34, SD=0.64), t_{11}=-2.92, p<0.01. However, no changes in negative affect before (M=1.72, SD=0.78) and after the game (M=1.68, SD=0.86), t_{11}=0.28, p=0.79 were found. The questionnaires revealed that gestures were perceived as suitable, and the game was perceived as easy and fun (see Tables 1 and 2), yet we did not find any connections between player performance and these phenomena. Participants noted that the game had a positive effect on their alertness: "*I'm a little more attentive than I was before.*" Once used to the game, some participants highlighted that more feedback and more in-game options would improve their experience: "*I wish more would have happened, like every time I moved.*" The participants generally liked the graphical style and theme of the game: "*Oh, that [game] is cute.*"

3.5.2 Performance Metrics

The technical implementation of the Kinect game was successful as the performance logs showed no tracking failures. Completion results for hand and arm-based gestures were high (100% for raising arm, 100% for moving arm(s) to the side(s), and 92% for catching the bird), whereas only one participant was able to perform foot-based gestures. Out of the twelve participants, eleven persons participated in free play.

3.5.3 Observations

Observations showed that most of the participants could interact with the game. Often, participants needed additional explanations. There were a few differences between guided play during the tutorial and the period of free play that followed it. Only some participants could correctly recall interaction paradigms after the tutorial and interact with the game on their own, whereas others needed assistance from the experimenters to perform correct movements. Also, some participants showed physical fatigue after interacting with the game over longer periods of time. From a technical perspective, Kinect tracking worked well despite participants sitting in wheelchairs.

3.6 Findings

Based on the results, we conclude that institutionalized older adults generally enjoy engaging in full-body interaction games, and that the garden-themed game design presented in this paper appealed to the audience.

However, results also show that most participants could not participate in free play on their own. This lends itself to the conclusion that free play is not suitable for elderly without prior gaming experience. For most of our players, recalling gestures was too challenging on their own. While proper game tutorials for institutionalized older adults remain to be explored in future work, one possible solution might be to introduce longer training periods for all gestures or designing game mechanics that suggest

Table 2. Descriptive statistics for items examining the perceived suitability of the game (5 = completely agree).

Item	Mean	SD
Playing the game was fun.	3.79	0.99
Playing the game was tiresome.	2.13	1.57
Playing the game was easy.	3.71	1.48
Playing the game was difficult.	1.83	1.11

gesture affordances. For example, picking apples from a tree would trigger a known gesture and might be an easier game mechanic. Also, some of the participants seemed to be more alert and awake during the second part of the study, while others were less engaged. Therefore, an individual gesture adaptation is not only necessary to accommodate different players but also to account for within-player variances that we observed.

4. DISCUSSION

The work presented in this paper looks specifically at the challenges of designing full-body motion-controlled games for institutionalized older adults. In this section, we discuss the significance of our observations during the evaluation, the need for adaptable gestures and systems, and the positive effect that gesture-based games may have on the emotional well-being of institutionalized older adults.

With a growing number of senior citizens, games may contribute to their well-being in full-time care, as physical activity is crucial for well-being in old age. Yet, certain limitations have to be considered. When we compare gesture-based interaction using the Kinect to that of other gesture-based interfaces, the Kinect has clear benefits over the competition. Compared to other devices such as the Nintendo Wii Remote or PlayStation Move controller, the lack of a handheld controller becomes a clear advantage. The use of the Kinect allows for more natural interactions, and frees designers from the worry of arthritic hands holding a controller. Players (who are often unfamiliar with traditional handheld controllers in the case of older adults) are able to interact with the game directly. Our research results show that the elderly can interact with games, enjoy playful activities and have the desire to stay more active, which can be supported by video games. However, common design practices balance the challenge of a game around the abilities of younger players, and diverse physical and cognitive abilities of older adults make the use of commercial games problematic. Therefore, gestures used in such games must be adaptable to facilitate all player types.

Most Kinect games require players to stand, have use of two arms and legs, good vision, quick reactions, and knowledge of the interaction with video games. Therefore, current generations of full-body motion-controlled games are inaccessible not only to institutionalized older adults but to many players, e.g., children experiencing mobility disabilities. One of the main issues is that commercially available games only calibrate games according to player position to optimize tracking results. We believe that this calibration process has to be augmented to provide an inclusive approach towards motion-based game design. By implementing a calibration routine that considers individual abilities, we provide a means of including broad audiences in motion-based gaming. In our study, we demonstrated that this approach offers the opportunity of allowing older adults to engage with digital games, and we believe it may be useful for general audiences to adapt games to individual player skills.

When we combine the potential cognitive and physical benefits of full-body motion controls, the large potential of games having a positive effect on institutionalized older adults is revealed. Perhaps the most valuable outcome from our study was the positive effect playing video games had on the mood of the participants. We found that participants enjoyed the experience of playing the game by indicating a more positive affective state. A prolonged positive affective state leads to an overall increase in positive mood [6]. Players who have a positive experience are more likely to continue to play, and return at a later point. In this context, it is important to highlight that we understand games as a means of supplementing the life of older adults. To preserve positive effects, we recommend applying games as a gateway to new experiences rather than a replacement of other activities.

5. FUTURE WORK AND CONCLUSION

Research should explore on-screen instruction for institutionalized older adults. Our results suggest that it is likely that institutionalized older adults will generally respond more positively to guided experiences. Additionally, an evaluation of possible benefits of engaging with full-body motion-controlled games is necessary with a focus on the investigation of positive cognitive and physical effects. In terms of game design for older adults, we plan to implement a game for nursing homes designed to engage residents for a longer period of time, and explore the long-term effects of engaging with games on the physical and emotional well-being of older adults.

Older adults in nursing homes frequently lead sedentary lifestyles and therefore experience a reduced quality of life leading to decreased life expectancy. Over the past few years, there has been an increase in motion-controlled video games, which hold the promise of engaging users in physical activity. However, there has been little research regarding the design of motion-controlled games for diverse audiences, resulting in little understanding of how to ensure that interaction techniques are functional for older adults. Our work is a first step in this direction. Through our study of motion-control for institutionalized older adults, we have exposed the limitations of current design philosophies and highlighted design opportunities to facilitate the creation of accessible motion-controlled video games. If full-body motion-controls are to enjoy the same acceptance as other interaction techniques, we must ensure that entertainment technologies remain an accessible and enjoyable activity for all audiences, including older adults.

6. ACKNOWLEDGMENTS

We thank Saskatoon Health Region and Sherbrooke Community Centre for supporting our research, and the participants for their contribution during the evaluation phase. We thank NSERC, SURFNET, and the GRAND NCE for funding.

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