Visual Complexity, Player Experience, Performance and Physical Exertion in Motion-Based Games for Older Adults

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ABSTRACT
Motion-based video games can have a variety of benefits for the players and are increasingly applied in physical therapy, rehabilitation and prevention for older adults. However, little is known about how this audience experiences playing such games, how the player experience affects the way older adults interact with motion-based games, and how this can relate to therapy goals. In our work, we decompose the player experience of older adults engaging with motion-based games, focusing on the effects of manipulations of the game representation through the visual channel (*visual complexity*), since it is the primary interaction modality of most games and since vision impairments are common amongst older adults. We examine the effects of different levels of visual complexity on player experience, performance, and exertion in a study with fifteen participants. Our results show that visual complexity affects the way games are perceived in two ways: First, while older adults do have preferences in terms of visual complexity of video games, notable effects were only measurable following drastic variations. Second, perceived exertion shifts depending on the degree of visual complexity. These findings can help inform the design of motion-based games for therapy and rehabilitation for older adults.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for people with disabilities*; K.8.0 [Personal Computing]: General – *Games.*

General Terms
Design, Experimentation, Human Factors.

Keywords
Older adults, serious games, motion-based games, visual complexity, accessibility, design, entertainment.

1. INTRODUCTION
Older adults face significant health challenges ranging from age-related changes resulting in reduced cognitive performance and resilience, as well as reduced physical abilities, acute disease and age-related illnesses, such as dementia, stroke, or injury [4,9,13].

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In rehabilitation from acute -or treatment of chronic- disease and for general health preservation and prevention, sports, other motion-based activities, and physiotherapy play a central role [4,9,14]. In this context, motion-based games are increasingly applied as a means of motivating players to follow through with persistent and often repetitive exercises or therapy routines [3,7,12,21]. Such *kinesiatric serious games* (KSGs) can also offer guidance and feedback concerning the correct execution of exercises, the players' status and progress [2], and can lead to combined physiological and cognitive benefits [1].

Due to the immediate impact on the accessibility of motion-based video games, existing work in the field of motion-based game design for older adults has focused on creating adequate and engaging interaction paradigms [12] and game mechanics [13]. However, there is evidence that the visual design is another important factor in game design for older adults: prior work reports that simplistic graphics may allow older adults to focus on the core elements of gameplay [11], and that highly immersive motion-based games increase the risk of injury if players do not pay attention to their own movements, which is particularly important when designing for older adults who experience changes in posture and gait. Furthermore, anecdotal evidence suggests that engaging games can encourage older adults to engage in physical activity although they experience pain. In this context, it is important to consider the impact of age-related changes and impairments if older adults engage with games. On the one hand, changes related to sensory channels and actuation capabilities may change the way games are perceived; however, the visual style and fidelity are an important element of games and are closely tied to the aspects of immersion and flow [19], both of which contribute to the motivating power of games [8], which is pivotal when designing games to motivate players to participate in therapy. However, visual complexity (also referred to as *graphical fidelity*) may also become a limiting factor regarding game accessibility, particularly with highly complex experiences, which may be overwhelming, with high graphical fidelity being a distraction rather than a source of enjoyment.

In this paper, we explore the impact of visual complexity in motion-based games for older adults. We report on a comparative study using a motion-based game that was originally designed for physical therapy for persons with Parkinson's disease (PD) and later adjusted for usage with older adults. We developed four versions of the game implementing different levels of graphical fidelity, and we evaluated these games with fifteen older adults, focusing on the impact of visuals on player experience, in-game performance, and physical exertion. Our results show that although visual complexity does not influence player experience and performance, older adults report higher levels of perceived exertion for abstract visualizations, and express an overall preference for high-fidelity graphics. Our work makes the following contributions: We provide a controlled comparison of the effects of visual complexity on player experience, performance and perceived exertion in motion-based games for older adults. Furthermore, we outline the implications of our findings for game design, and we contextualize our findings beyond entertainment to help inform the design of games for therapy. If motion-based games are to be applied in physical therapy and rehabilitation, it is important to arrive at a full understanding of factors that influence their impact on older adults. Our work is a first step towards helping designers provide safe, accessible and enjoyable gaming experiences for their audiences, encouraging a broader group of older adults to play video games, and allowing them to benefit from the application of KSGs in therapy.

2. VISUAL COMPLEXITY IN GAME DESIGN FOR OLDER ADULTS

The central output modality for most video games is the visual channel: most games remain playable without sound, whilst they are not playable without perceiving their visual representation. Frequently, information about the game state is conveyed through the graphical user interface and a more or less detailed rendering of the game world. The visual channel is therefore a key factor to be considered when creating games that must be as accessible as possible for heterogeneous target groups such as older adults. At the same time, adequate visual complexity and fidelity on a coherent, understandable, yet captivating level are a prerequisite to the immersive power of video games. The aspects of accessibility and immersion both need to be considered, if the potential benefits of motion-based video games are to be leveraged for target groups with broad spectra of eyesight limitations, such as older adults. For this specific target group, typical age-related vision impairments, such as glaucoma, cataract, or presbyopia appear in combination with a general decline in vision capabilities, ranging from reduced visual acuity [17], to limitations in transmission and accommodation, and a decline in color perception [18]. Related work on visual complexity of game interfaces for older adults has focused on these issues mainly by providing general design guidelines derived from medical facts [9,10]. Experimental insight in the application area of games for health remains sparse. Thus, while a reduction in the complexity of visual elements is suggested by previous studies [10,11], the extent of visual fidelity that best combines accessibility for older adults in KSGs with a rich and motivating game experience begs further exploration. In addition to the aspect of accessibility, visual fidelity is a (temporal and monetary) cost factor for game producers. Often, more realistic and arguably more complex graphics go along with an increased cost of production and increased hardware requirements. The production of alternative graphics sets to allow for customizable accessibility [16] is not always an option. Thus, the question which level of graphic fidelity should be targeted is an important managerial consideration in game production. Furthermore, it is linked to the accessibility and playability, the capacity of a game to induce flow and immersion, and provide a positive authentic player experience.

3. VISUAL COMPLEXITY IN MOTION-BASED GAMES FOR OLDER ADULTS

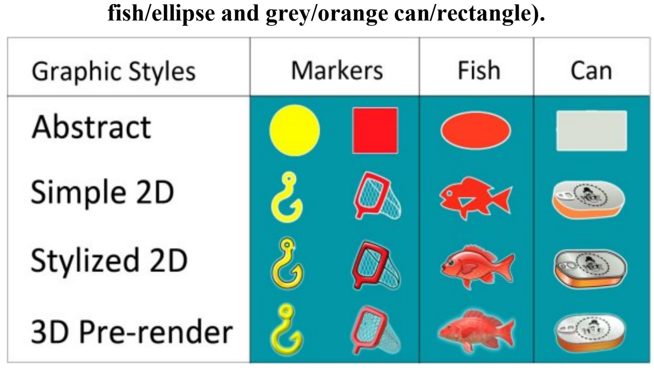
In order to investigate the continuum of possible game graphic fidelity, a classification scheme is required. McLaughlin et al. [19] offer a structured approach to the aspects that are related to game graphics by separating the concerns of *modeling* (form), *animation* (motion) and *rendering* (surface & lighting). Following these development concerns, the authors propose a taxonomy for common levels of computer graphics fidelity for use in entertainment media ranging from *simplified* over *stylized* to *realistic* (see Table 1).

Table 1: Summary of prominent graphics aspects of different levels of CG (computer graphics) fidelity according to [19].

Fidelity	Aspect	Style
Simplified	*Form*	Symbolic representations. Low level of detail.
	Animation	No figural articulation. Low motion-fidelity.
	Rendering	Flat shading; e.g., vector graphics.
Stylized	*Form*	Identifiable objects. Not necessarily realistic proportions. Level of detail can range from low to high.
	Animation	Articulation and deformation of figures present. Actions can be exaggerated. Motion fidelity varies with expressive requirements.
	Rendering	Shading of curved surfaces, transparency, texture mapping.
Realistic	*Form*	Photo-realistic modeling of familiar objects. Level of detail is high.
	Animation	Coordination systems defining both articulation and deformation. Motion accuracy is high.
	Rendering	Photo-realistic shadow casting, reflections, light scattering.

In the light of related work suggesting potential benefits of simplistic graphics [11], we extended this set by a class called *abstract*, which features minimalistic graphics where the visual entities are geometric shapes that do not carry their own symbolic micro-narrative, graphical elements may be moving but have no additional animations and the shapes are flat-shaded and single-colored. Table 2 provides an overview of the design of the active game-play objects for each of the four major classes of computer graphics fidelity. The levels were chosen as to facilitate a systematic experimental probing covering a continuum from low to high visual complexity. The basic categorization can be employed for the design of 2D or 3D games with any desired perspective. For the initial investigation presented by this study, all conditions were set to be 2D renderings. In order to make the specific interpretation of the general levels of fidelity explicit, the derived design classes were labeled *abstract*, *simple 2D*, *stylized 2D* and *3D Pre-render*.

Table 2: Different levels of visual complexity of the active game objects (yellow hooks/circle, red/grey nets/square, red fish/ellipse and grey/orange can/rectangle).



3.1 *WuppDi!* Games for PD Therapy: Visual Adjustments and Adaptation for Older Adults

The game prototype used for this study was based on the *WuppDi!* suite of motion-based games for Parkinson's disease patients [3], more specifically the game *Bremen Town Musicians* (Figure 1). In this game, players have to first stop game elements that are moving across the screen on a stable trajectory by touching them with one hand and then collect these elements by touching them with their other hand. The games of the suite were implemented as 2D games in C# and Microsoft Game Studio (XNA) using differential images and color-blob tracking (red and yellow hand-held markers) for determining relative motion and the position of the players' hands.

Figure 1: Screenshot of the original game called Bremen Town Musicians before adjustments and re-skinning.

In order to utilize the game for the purpose of this study, a number of adjustments were made, resulting in a game called *Fish Harvester* (for screenshots see Figure 2). The basic game mechanics focus on senior-friendly user input, therapy-appropriate wide and fluent movements, positive encouragement without punishments, and a simple interaction scheme, which was the result of a user-centered game design process. An evaluation of the *WuppDi!* suite showed that the games were well received and the implemented motion-patters were deemed adequate for the participating PD patients by therapists [3].

In the visually adapted (*Fish Harvester*) version of the game, we maintained the core mechanics. The *scenario* was changed to a fishing game in order to facilitate a more straightforward production of the abstract, simple 2D, stylized 2D, and 3D pre-render game skins. *Background animations* were removed, so that only active game objects display motion. The *color scheme* was adjusted to separate interactive objects (warm colors) from passive objects (cold colors) using complementary colors, in order to avoid adjacent parts of the hue circle. *State animations of the collectible objects* were adjusted to better separate stopped but not yet collected objects. *Motion trajectory randomization* was replaced by a predefined set of pseudo-randomized trajectories for collectible objects in order to support a better isolation of the independent variable of visual complexity across conditions. The *graphical user interface* was adjusted to match the new scenario, color scheme and the four levels of visual complexity. Figure 2 shows screenshots of the resulting four versions of the full game in an identical game-play situation. The game-situation pictured in these screenshots shows a number of fish-objects which are moving across the screen on fixed trajectories. The players control the position of a net and a hook with their right and left hand. The hook can be used to stop the fish-objects and these can then be collected by touching them with the net.

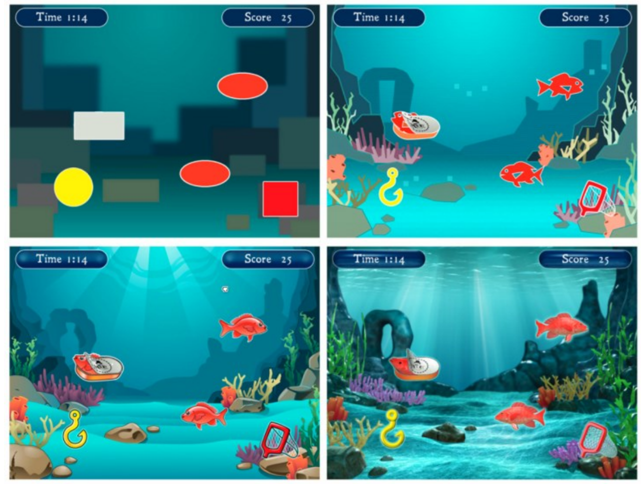


Figure 2: Screenshots of the four versions of Fish Harvester with different levels of visual complexity ranging from abstract (top-left), over simple 2D (top-right) and stylized 2D (bottom-left) to 3D pre-render (bottom-right).

4. EVALUATION

In order to investigate the impact of visual complexity on player experience we conducted an evaluation of the four game versions. We were particularly interested in the impact of visuals on immersion, enjoyment, game performance and perceived exertion. The following paragraphs describe the method and procedure employed to evaluate the impact of different levels of visual complexity on game experience and performance in motion-based games for older adults. The according hypotheses for each of the quantitative measures in the following description are H_0: *"There is no difference in player experience, performance, or physical exertion between the four graphically different versions of the game."* and H_1: *"There is a difference in player experience, performance, or physical exertion between the four graphically different versions of the game"*. Further analysis follows in cases where the null hypothesis was rejected.

4.1 Setup

The study followed a within-subjects design. Thus, each participant was asked to play each version of the game following a 4x4 Latin square permutated order to counterbalance training bias. A separate room was prepared for the experiment and equipped with a projector and screen for a large-scale game presentation, which is appropriate for motion-based games. The game ran on a gaming notebook with *Windows 7* installed and a webcam connected, which provided motion data for the tracking mechanisms. A video camera was positioned next to the screen, capturing the participants in a frontal full shot and including the current game scene as it was visible on the screen of the notebook running the game. The experiment conductor was present in the experiment room at all times.

4.2 Measures

We applied a range of measures to gain insight into the following aspects of player experience that each version of the game provided: *player experience*, *player performance*, and *physical exertion*.

Player experience. To gain insights into player experience, we applied different measures. Affective state was assessed using the self-assessment manikin (SAM) [6], which captures valence, arousal and dominance, the three main affective states. Furthermore, players provided their stance towards the following three statements (on a five-point Likert scale ranging from *1 – disagree* to *5 – agree*) about the preceding round of play: (S1) *"I found the visual elements to be easy to identify and follow."*, (S2) *"I felt deeply immersed in the game."* and (S3) *"I thought it was fun."* [1] We applied additional questionnaires and observations to assess player experience. In a series of statements following the completion of all four trials and the according post-trial questionnaires, participants were asked to rank all four versions they played (by ordering randomly sorted screenshots of the same game-scene for each version, as depicted in Figure 3) according to the following four prompts: (R1) *"Which version do you like best?"*, (R2) *"Please arrange the images according to how 'visually pleasing' you found the pictured game version."*, (R3) *"Please arrange the images according to how easy it was to 'identify moving elements' in the pictured game version."* and (R4) *"Please arrange the images according to 'which version you would like to play again'."* Further cues concerning the game experience were drawn from an *observation protocol* and from *post-study interviews* conducted with participants who were selected for notable demographic factors or peculiar behavior during play. Lastly, emotional facial expressions were coded based on the recorded video material for the following categories: *smiling*, *laughter*, *frowning*, and *sadness*.

Player performance. We tracked the following game metrics to examine in-game player performance and to obtain further insights into the way they interacted with the different versions of the game: Event logs for *task success* (number of fish stopped/collected divided by total number of fish) and *time on task* (time spent before collecting moving game objects divided by time available to collect moving game objects).

Physical exertion. The physical effort required to play Fish Harvester was assessed using two different measures. First, we tracked the *amount of movement* for each version of the game including *movement distance* (distance travelled with each hand in pixels on screen), counting *footsteps* and *tracking-error detection* (applied to correct game log analysis) based on annotations of the video recordings and related aspects collected in the observation protocols. Second, we applied the *BORG rating of perceived exertion* (RPE) [5] as a subjective measure of exertion to gain insights into whether the visual complexity of games has an impact on perceived player exertion.

4.3 Participants and Procedure

Fifteen older adults (2 male, 13 female, average age: 73.6 years, ranging from 61 to 85 years of age, SD=7.77) participated in the evaluation. None of the participants were diagnosed with color vision deficiency, however only one participant did not have eyesight limitations. Six participants reported prior computer experience. The participants were recruited on a voluntary (no monetary compensation) basis from a local casual gymnastics and motion-based activities group, as well as from afternoon language learning and tabletop gaming groups for older adults, which meet weekly at the *FQZ Neue Vahr* in Bremen, Germany.

Participants were greeted by the experiment conductor following a fixed script. They were informed about the procedure of the experiment and their consent to participation and to data analysis was obtained. The participants then answered a pre-experimental questionnaire containing a number of basic demographic items, as well as questions about their eyesight, sports habits, computer usage, and gaming habits. They also completed the BORG RPE, as well as a self-assessment manikin (SAM) to gather baseline information. Following a short training period with the original *Bremen Town Musicians* game, which included an introduction by the conductor and provided around one minute of actual gameplay, each participant played one round of all four versions of the *Fish Harvester* game, lasting exactly 2 ½ minutes. Each round of playing the game was followed by a post-trial questionnaire consisting of a BORG RPE, a SAM and the three game experience self-report questions (S1 – S3). After the final round, the participants responded to an additional survey, which included the ranking questions (R1 – R4) and the option to provide feedback about their experience of participating in the study.

In order to create an experimental procedure which is well accomplishable for older adults and to reduce bias introduced through social norms, lack of computer knowledge and to avoid misunderstandings [20] the following adjustments were made that present purposeful deviations from standard experimental procedures: All pre-study, post-trial and post-study questionnaires were presented as structured interviews and answers were provided by pointing on printed scales for SAM and BORG items, ordering game screenshots (for the rankings) or by verbally uttering a choice on the Likert scale range ("one" to "five"). Participants were offered to take a break (with an optional drink of water) following each trial and the procedure was setup to be limited to a maximum duration of 45 minutes per participant.

Figure 3: Photographs of participants completing the survey elements. Left image: a participant responds to an item of the SAM. Right image: A participant ranks the four versions of the game by ordering cue-cards with screenshots of the game.

4.4 Results

In this section, we summarize our findings regarding player experience, player performance, and physical exertion when playing Fish Harvester. Results from fifteen participants were processed after two records had been removed from the analysis; one due to low age, and one due to communication problems when processing the questionnaires.

4.4.1 Player Experience

An analysis of the SAM responses across conditions and prior to play showed an increase in the overall high mean scores for *valence* (simple2D: M=4.2, SD=0.68; stylized2D: M=4.4, SD=0.63; 3D pre-render: M=4.2, SD=0.76) with a notable difference after playing the abstract version (M=4.07, SD=0.7), when compared to the before gameplay measurement (M=4.07, SD=0.7). The scores for the overall low to medium *arousal* were all increased when compared to the prior-to-play condition (M=2.2, SD=0.86), with the abstract condition (M=2.4, SD=0.83) displaying the largest increase for all four versions of the game

[1] All questions and quotes were translated from German.

(simple2D: M=2.27, SD=1.03; stylized2D: M=2.27, SD=0.96; 3D pre-render: M=2.33, SD=0.9). The scores for the overall medium to elevated *dominance* increased for all versions of the game, when compared to the prior-to-play measurement (M=3.13, SD=0.74), with the abstract condition showing the smallest mean (M=3.4, SD=0.83) of all game versions (simple2D: M=3.6, SD=0.99; stylized2D: M=3.6, SD=0.99; 3D pre-render: M=3.8, SD=1.08). A repeated measures ANOVA at significance level α=.05 showed no significant differences between average scores for the valence or the arousal measure across conditions. A $p<0.05$ significant difference in average scores for dominance between conditions was found ($F(4, 56)=2.935$, $p<0.028$) with post-hoc pairwise comparison revealing that the mean level of dominance reported when playing the 3d pre-render version (M=3.80, SD=1.08) was significantly higher than before playing games (M=3.13, SD=0.74, $p<0.012$) and when compared to the responses which were provided following the abstract version (M=3.40, SD=0.828, $p<0.028$).

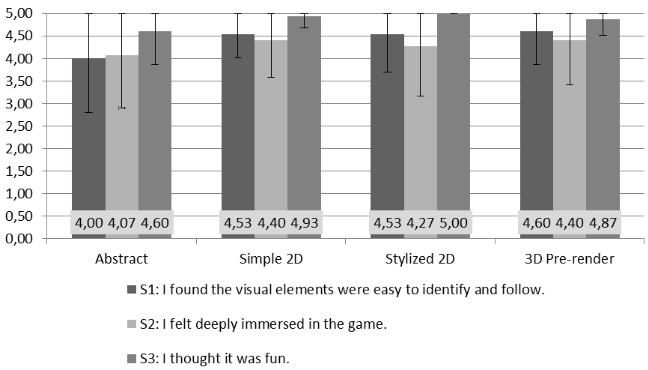


Figure 4: Participants' mean responses to game experience statements S1 - S3 following each condition.

Concerning the three post-trial game experience statements (S1 – S3), the participants of the study responded with the lowest average score for each statement after playing the abstract version of the game (see Figure 4 and Table 3). However, no significant differences were found between conditions in an ANOVA for each statement.

Table 3: Participants' mean responses and response standard deviations for game experience statements S1 - S3.

Q1	*I found the visual elements easy to identify and follow.*			
Q2	*I felt deeply immersed in the game.*			
Q3	*I thought it was fun.*			
	Mean (SD)			
	Abstract	**Simple 2D**	**Stylized 2D**	**3D Pre-render**
Q1	4.00 (1.20)	4.53 (0.52)	4.53 (0.83)	4.60 (0.74)
Q2	4.07 (1.16)	4.40 (0.83)	4.27 (1.10)	4.40 (0.99)
Q3	4.60 (0.74)	4.93 (0.26)	5.00 (0.00)	4.87 (0.35)

Observations showed that all participants were able to play the game in all four versions although we observed differences in the participants' individual physical abilities. The input method based on hand-held colored marker sticks was easily understood, with some participants explicitly remarking on the ease-of-use, e.g. *"Ah, this is a lot easier than the mouse."* All participants reported having fun while playing the games, even though some mentioned reservations towards playing motion-based digital games during recruitment. Some participants had problems with the mapping of the representation of the markers in the game to their left and right hand in the beginning of the game. However, all participants managed to overcome these problems quickly and the game mechanics were setup to be forgiving, providing positive feedback in any case.

4.4.2 Player Performance

Repeated measures ANOVAs performed for the game log measures of average *number of stopped collectible game objects* [CGOs out of 49] (abstract: M=42.93, SD=8.64; simple 2D: M=42.07, SD=6.81; stylized 2D: M=44.13, SD=8.05; 3D pre-render: M=43.13, SD=7.62), *average time needed to stop CGOs* [in seconds] (abstract: M=3.25, SD=1.02; simple 2D: M=3.42, SD=0.82; stylized 2D: M=3.02, SD=1.01; 3D pre-render: M=3.02, SD=1.19), *average number of collected CGOs* (abstract: M=41.20, SD=9.15; simple 2D: M=40.93, SD=7.69; stylized 2D: M=43.07, SD=9.22; 3D pre-render: M=41.93, SD=8.52) and *average time needed to collect CGOs* (abstract: M=5.48, SD=7.03; simple 2D: M=2.49, SD=2.76; stylized 2D: M=1.64, SD=1.51; 3D pre-render: M=2.34, SD=2.82) showed no significant differences.

4.4.3 Physical Exertion

The average levels of exertion reported by the participants on the RPE scale (6-20 pt. scale, roughly equivalent to 60-200 heartbeats per minute) fell within the intended *very light* (9) to *fairly light* (11) spectrum. The mean score showed slight increases for every version of the game when compared to pre-study levels and the participants expressed the highest perceived exertion after playing the abstract version of the game (cf. Figure 5).

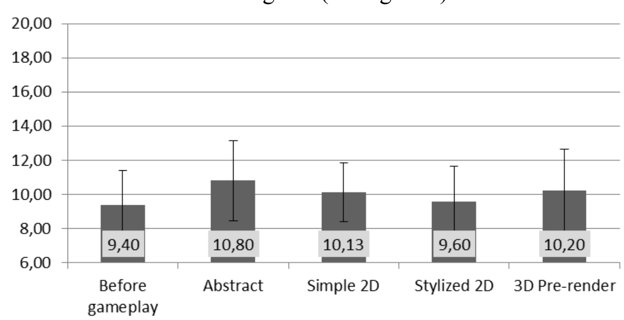


Figure 5. Mean response to Borg's RPE scale before gameplay and after playing each version of the game.

A repeated measures ANOVA showed a statistically significant difference at the $p<0.05$ level ($F(4, 56)=2.891$, $p<0.03$). A post-hoc pairwise comparison using the Bonferroni correction indicated that the participants' perception on their level of exertion after playing the abstract version (M=10.80, SD=2.37) was significantly different from before playing the games (M=9.40, SD=11.99, p=0.043) and from the stylized 2D version (M=9.60, SD=2.063, p=0.034). In contrast to these findings regarding perceived exertion, video coding annotating the number of footsteps was analyzed with a Friedman test, and showed no significant differences between the four game versions at α=.05 (N=14, $X^2(3)=3.25$, p=0.36), suggesting that the objective level of exertion was similar across conditions. The comparison between left-hand and right-hand travel distance per condition based on event log data, while exhibiting the largest values for the abstract version, also showed no significant differences.

4.4.4 Rankings

The comparative rankings were analyzed by assigning scores from 4 to 1 in decreasing order from the highest ranked to the lowest ranked game version for each individual ranking. A Friedman test was applied to each of the four rankings (sig. level α=.05) and post-hoc Bonferroni corrected Wilcoxon Signed-Rank tests ($p<0.0125$) were employed to identify the differences between conditions in the case of significant differences within the rankings. Concerning the ranking R1 (*"Which version do you like best?"*) the 3D pre-render (M=3.0, SD=1.25) and stylized 2D (M=3.0, SD=0.76) versions had the same average score followed by simple 2D (M=2.67, SD=0.81) and lastly abstract (M=1.33, SD=0.72).

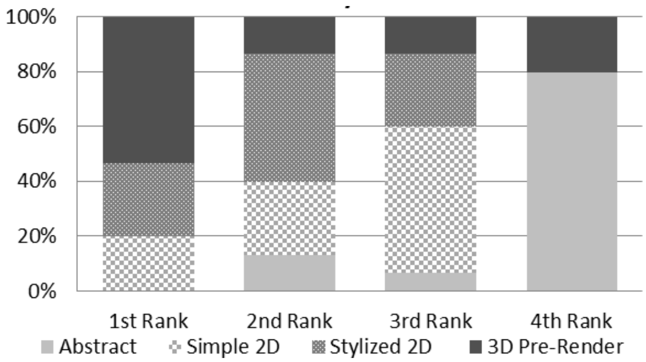


Figure 6: The responses of the participants to ranking item R1 ("Which version do you like best?"). The abstract version is least preferred.

There was a significant difference in the averages ($\chi^2(3)=17$, p=0.001) and the post-hoc test showed significant differences between the abstract version and all other versions of the game [abstract vs. simple 2D (Z=-3.573, p=0.000), abstract vs. stylized 2D (Z=-3.187, p=0.001) and abstract vs. 3D pre-render (Z=-2.724, p=0.006)]. For the ranking R2 ("*Please arrange the images according to how "visually pleasing" you found the pictured game version.*"), the 3D pre-render version received the highest rankings (M=3.07, SD=1.39), followed by the stylized 2D version (M=2.73, SD=1.03), the simple 2D version (M=2.13, SD=0.99) and lastly the abstract version (M=1.4, SD=0.99). These averages showed a statistically significant difference ($\chi^2(3)=15.514$, p=0.001) with a pairwise comparison indicating a significant difference between the abstract version and the stylized 2D version of the game (Z=-2.612, p=0.09). The third ranking (R3: *"Please arrange the images according to how easy it was to "identify moving elements" in the pictured game version."*) again favored the 3d pre-render version of the game (M=3.07, SD=1.22) over the stylized 2D version (M=2.47, SD=1.19), followed by the simple 2D version (M=2.4, SD=0.99) and the abstract version (M=1.4, SD=1.12). Following an H_0 rejection in the Friedman test ($\chi^2(3)=13.8$, p=0.003), significant differences were found between the abstract and the simple 2D (Z=-2.514, p=0.012), as well as the abstract and the 3D Pre-render (Z=-2.731, p=0.006) version. The last ranking (R4: *"Please arrange the images according to "which version you would like to play again"."*) was also won by the 3D pre-render version (M=3.13, SD=1.25), followed by stylized 2D (M=2.6, SD=1.06), simple 2D (M=2.2, SD=1.08), leaving the abstract version on the last place (M=1.4, SD=1.06). After a positive significance indication for this ranking ($\chi^2(3)=15.43$, p=0.001), significant differences were found between the abstract version and the stylized 2D version (Z=-2.51, p=0.012), as well as the abstract and the 3D pre-render version (Z=-2.86, p=0.004).

4.5 Findings

On a general level, the results are in line with previous evaluations of the *WuppDi!* suite of games for physical therapy. Our findings indicate that Fish Harvester was accessible to older adults, produced a positive player experience and light levels of exertion. Regarding player experience, the findings show that participants enjoyed playing the game across all conditions regardless of visual complexity, suggesting that the level of graphical detail does not have a large impact on the affective state and enjoyment of players while engaging with the game. Participants reported high levels of valence and arousal along with rising dominance and high immersion and fun after playing the game in each of the conditions. However, explicit statements regarding game preference contradict this result; participants selected high-fidelity versions of Fish Harvester over the abstract version of the game. Findings regarding physical exertion have two implications. On a general level, participants reported light perceived exertion, suggesting that the game was slightly challenging, but that it was not exhausting, and that playing the game did not take too long. Objective measures support this result and outline that levels of exertion were constant across conditions. Hence, perceived and objective exertion results do not provide a distinct picture. While the RPE responses and the arousal responses increased most following the abstract condition, the respective amounts of increase are relatively small and the results of the performance based on game log analysis do not indicate any strong objective differences in exertion, suggesting that visual complexity has an impact on how physical activity is perceived.

When comparing between conditions, most of the significant results can be interpreted to indicate a rejection of the abstract version of the game, while few differences were detected between the other three styles. This is supported by small increases in valence and dominance, as compared to before gameplay and to the abstract version, by consistently higher means in the participants' responses to the game experience items S1 – S3 and most explicitly by the large number of statistically significant H_0 rejections in the analysis of the ranking questionnaire results, with post-hoc comparisons consistently pointing at differences between the abstract version and the other game versions. The game versions are consistently ranked in the same order (decreasing) from *3D pre-render* (1st place) over *stylized 2D* (2nd place) and *simple 2D* (3rd place) to *abstract* (4th place). However, the differences between the first, second and third place are minute.

5. DISCUSSION

The work presented in this paper explores the impact of visual complexity on player experience, performance, and exertion in motion-based games for older adults. The results show an interesting relationship between these three factors: Although older adults preferred high-fidelity graphics when asked to explicitly rank different versions of Fish Harvester, visual complexity does not have an impact on player experience participants reported immediately after engaging with each of the game versions. However, results show that visual complexity does influence the way exertion is perceived, with participants reporting higher levels of exertion when playing a low-fidelity version of Fish Harvester. In the following sections, we discuss the implications of these findings for motion-based game design for older adults, and we suggest how our findings can be applied to the design of games for therapy and rehabilitation.

5.1 Player Experience and Game Preference

Our study shows that the different levels of visual complexity of *Fish Harvester* do not have a significant impact on player experience. Since the overall level of player experience was positive, this suggests that older adults may not appreciate graphical detail as much as younger audiences with extensive gaming experience might. While it may be tempting to conclude that game design projects targeting older adults need not dedicate extensive resources to the graphical design, a closer look at our results reveals that this may be an error that might lead to reduced acceptance of video games among older adults in the long run.

When assessing the importance of graphical fidelity in motion-based game design for older adults, it is important to take into account that explicit ratings contradict this result; participants consistently ranked the non-abstract versions of the game higher than the abstract version when asked to explicitly rate the games. This may be an interesting factor when considering the context in which older adults play games, particularly when designing games for entertainment. With a wide range of motion-based games being available, prospective players can choose from a number of games. Keeping in mind older adults' preferences, creating high-quality game graphics may give game developers a competitive advantage if we interpret our findings in a way that suggests that older adults would be more likely to choose a game featuring high-fidelity graphics. Likewise, the impact of graphical fidelity needs to be considered when designing games for therapy and rehabilitation. Although the visual complexity of the game may not have a direct impact on therapy outcomes in the sense that players will still enjoy short-term engagement, players may not have a choice in the games they engage with as they are defined by the therapeutic context, and player motivation may be largely extrinsic, appealing graphics may still be of some importance: integrating graphics with other game content allows players to easily relate to in-game events, which may foster long-term motivation, and help increase the acceptance of motion-based games amongst older adults.

However, apart from these basic considerations regarding the impact of abstract representations and high visual complexity in motion-based games for older adults, our results show no strong preference of participants for any of the specific non-abstract versions of *Fish Harvester*. This suggests that, while some level of visual complexity is necessary to convey the micro-narrative of casual games, it may be sufficient to provide casual visual complexity in motion-based games for older adults, which would allow developers to focus remaining resources on other aspects of game design, such as the creation of accessible interaction paradigms. In this context, it is important to consider the influence of visual complexity on objective and perceived physical exertion, which we discuss in the following section.

5.2 Perceived Exertion and the Risk of Injury

Our results demonstrate an increased perceived level of exertion in the abstract version with drastically reduced visual complexity, while objective measures of exertion show that actual physical effort does not appear to be significantly different across all conditions. This confirms previous findings of physical exertion in games for all audiences suggesting that engaging experiences have a moderating impact on perceived physical effort [3] for older adult audiences. While this aspect may be desirable if games try to encourage exertion among younger, able-bodied audiences, it needs to be balanced carefully when designing motion-based games for older adults.

Prior work has addressed the issue of overexertion among older adults engaging with motion-based games. Anecdotal evidence shows that older adults are likely to engage with games despite physical pain, and recommendations regarding full-body motion-based game interaction for older adults highlight that game designers need to pace their games in a way that encourages healthy levels of physical effort among players [12]. Our results suggest that the design of game graphics may be leveraged to support this goal by increasing or decreasing the visual complexity: adjusting the visual complexity may be a means of moderating the risk of injury through increasing player awareness of physical exertion. This can be a design opportunity when addressing potentially vulnerable audiences or creating motion-based games for therapy and rehabilitation. In this context, the effect could also be applied to support therapy goals. If it is necessary for players to push through uncomfortable exercises to reach therapy goals, rich graphical experiences may be applied to deliberately decrease the level of perceived exertion, whereas abstract representations can be applied to encourage patients to focus on their proprioception.

6. LIMITATIONS

There are five major limitations related to the work presented in this paper. First, the ongoing presence and involvement of the experimenter during the evaluation phase is likely to introduce an experimenter bias, and we expect the effect to be amplified by the increased involvement of the experimenter, which was necessary to accommodate our target audience. Although we produced a strict script in order to avoid differences between conditions, the overall high levels of positive game experience must be interpreted in the context of study participants engaging with these games in a supportive atmosphere. Second, as noted above, the game was intended to be accessible by all players from the target group and thus, we expected low changes in arousal and exertion. Guidelines for adequate self-paced exercise suggest RPE levels of 11 to 14 even for stroke survivors [15]. Therefore, slightly higher levels of physical challenge might be targeted in future studies. Third, the gameplay duration per condition was limited due to the within-subjects design, and performance is likely to change after prolonged periods of play. Furthermore, the large heterogeneity in the target group is a challenging factor. Varying individual levels of visual acuity, whilst standing in common-sense agreement with the indication of a lack of differences between the three levels of complexity carrying symbolic narrative, beg further differentiation. Lastly, Type II error has to be considered a possibility due to the low number of participants and also due to the potentially reduced instrument reliability in the context of the setup of this study.

7. FUTURE WORK

Future work should investigate long-term effects of visual complexity on player engagement to gain insights into the development of player motivation over a longer period of time. In this context, exploring the impact of visual complexity on player experience should include a larger range of game genres. Increasing game complexity may be a means of allowing for a more detailed analysis of player experience and performance; applying additional measures to investigate psychological and physiological effects and an investigation of the relationship of game graphics, game mechanics, and game interfaces could provide further insights into the effects on player experience among older adults. All of these aspects are particularly important when considering the integration of motion-based games in therapy and rehabilitation settings as they are relevant to the overall player experience, and may contribute to failure or success of the application of such games.

8. CONCLUSION

In this paper we reported on an investigation of the impact of visual complexity on player experience, performance and exertion in motion-based video games for older adults. We conducted a study with fifteen older adult participants who were invited to play four different versions of an adapted motion-based game that was originally designed to provide physical therapy for persons diagnosed with Parkinson's disease. While we could not find any performance differences between game versions, our results suggest that visual complexity does influence how players rate the overall appeal of games, and how they perceive physical exertion.

Given recent efforts towards applying motion-based video games in physical therapy and rehabilitation for older adults, it is important to arrive at a detailed understanding of the effects of such games on players. Our work provides first insights into the impact of visual complexity of motion-based games on older adults. Our findings can help inform the work of game designers and assist them in their efforts of creating safe, accessible, and engaging experiences by selecting adequate in-game graphics. Moderating the way physical exertion is perceived through the visual design of games is a promising design opportunity in the context of therapy; it could help older adults overcome tedious repetitive elements of physical therapy and help them focus on the responses of their bodies when necessary, potentially improving the overall therapy experience.

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