Using Exergames to Train Patients with Dementia to Accomplish Daily Routines

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ABSTRACT

Many people with dementia (PwD) often have serious problems with basic everyday motor-cognitive tasks such as brushing their teeth, grasping objects, putting clothes on, or communicating with others. The challenges of these daily activities increase over time for PwD, but can be opposed with regular exercises. Virtual reality (VR) exergames have enormous potential to provide virtual scenarios, which could potentially reduce the progress of neuronal degeneration by motivating PwD to train their daily routines.

In this work-in-progress (w.i.p.) paper, we introduce the concept and development of a VR exergame for PwD. This VR exergame provides personalized motor-cognitive therapy for performing actions of daily routines in a gamified scenario. The focus is to create suitable exercises and further evaluate their completion to provide an optimal training scenario for improving everyday skills of PwD. Finally, we discuss the implications and next steps of this project.

KEYWORDS

virtual reality; dementia; exergame; health; everyday vr

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1  BACKGROUND & MOTIVATION

Already today, approximately 10% of people over the age of 65 suffer from dementia, the most common forms being Alzheimer’s disease and vascular dementia [7]. Due to demographic change we can expect a significant increase in the population of senior residencies with an older age structure. Therefore, we will observe more and more people suffering from dementia [1]. The above mentioned neurological diseases can manifest in a progressive decline in language, perception, memory, or reasoning [26]. These cognitive impediments, along with a general decline of physical...
abilities in this age group, frustrate patients and significant others, and increase the required hours of care for caregivers. In the interest of PwD, significant others, and caregivers, it is essential to maintain the required skills for daily activities of PwD as long as possible. Previous work has shown that different cognitive and physical combination training methods can reduce the neurological degeneration [11, 14, 15].

This work-in-progress paper describes one game of a multi-game project with the focus of treating older adults with slight forms of neurological diseases [27]. In the first game, we developed an exergame that focused on slow movements and cognitive stimulation by re-experiencing 360° scenes of the player’s city [28]. In the conductor style game introduced in this paper we provide players with a higher pace and shorter cues for decision making to provide more challenging scenarios for patients with milder forms of dementia. Therefore, we aligned the exercises with recommendations of physiotherapists and clinical experts to help the PwD maintain some everyday capabilities. We developed the games in close cooperation with experts and patients with the Hospital zum Heiligen Geist (HzHG), the largest hospital for older adults in Hamburg in northern Germany. Our development methodology is based on the Human-Centered Design (HCD) approach [18]. However, the special needs of PwD require adaption of typical HCD processes (e.g. more focus on observed feelings as opposed to interviews in section 1.2).

1.1 Serious Games for PwD

At senior residences, the residents typically have free time at their disposal, which can be used for participating in routine exercises and cognitive training [3]. As a part of these programs, serious games can be used to train older adults’ everyday skills by offering immersive experiences. These experiences can help by improving physical as well as cognitive abilities [13, 23, 31–35]. While our first exergame [28] focused on providing a platform for reminiscence activities, the current exergame only works with short term events. Previous work suggests that PwD can be engaged with virtual experiences [30]. Furthermore, VR experiences create positive emotions which can be shared by PwD, caregivers, and significant others [6, 17].

VR exergames aim to apply physical movements to VR games to improve motor-cognitive skills of people. In the work of Eissapour et al. [9, 10], upper body motions like reaching movements, lifting arms and rowing motions were performed while doing activities on a virtual farm. The study yielded that the participants achieved a greater range of motion than their therapists expected. Other approaches [33–35] created and evaluated four balance and coordination games with PwD. In these games, PwD performed physical movements from the OTAGO-exercise catalog using MS Kinect [5, 21]. The exercises focused on the lower and upper limb muscles while playing games like apple-picking, taking a walk through a virtual park, or steering an airplane. They addressed improvements on gait, coordination, mobility, balance, and the stability of patients. Finally, for the scenario we describe here, it is essential to consider, that research points towards music being a potent stimulus for PwD [8].

1.2 Human-Centered Design Approach

HCD focuses on understanding users, their motivation, and their needs [12, 22]. PwD should be seen as a person, and not just as their symptoms [17] and the designed applications should be as intuitive for them as possible. However, PwD are often limited in their ability to verbally express their thoughts [3, 19]. Obtaining information from their body language or people who are close to them plays an essential role during the design process [6, 17, 30, 35]. Therefore, working closely with all stakeholders including family members, formal and informal caregivers, physiotherapists, and dementia experts is an important prerequisite [9, 33, 35].

Through HCD, it can be shown that, with the help of all involved stakeholders, applications can be designed that are intuitive to use and adjusted according to the individual needs of the PwD [4, 9, 29]. Additionally, the social engagement of PwD and conversations between them and their caregivers and family can be established, fostering meaningful relationships [33–36].

2 Exergame Implementation

Following the HCD approach, all design choices are based on insights gained through our focus groups and interviews with experts from the prior phase of the project (See Section 3). Our primary focus at this stage is the accurate presentation of the exercise procedure and the evaluation of the participants’ accuracy in following the visual guide. Therefore, the players are immersed in a 3D concert hall with three musicians as the main points of interest. They can choose one of 6 popular songs to play and are then instructed to follow a 3D virtual tunnel (See Figure 1) with their controller, which is depicted as a conductor’s baton in VR. The tunnel is made up of three essential parts:

- The torus which the player is supposed to follow with the tip of the baton.
- The transparent tunnel extends before and after the torus to help the player anticipate the target’s path.
- Notes regularly spawned along the tunnel, which we use as markers to calculate the player’s accuracy when the torus hits each note.

The songs are split into the individual music instruments using Spleeter [16], so that we can use them individually for our three musician actors.

2.1 Game Design

Our conductor game is inspired by Wii Music [24], which includes an orchestra mode in which the player waves the controller around like a conductor’s baton. Additionally, there is a large variety of exergames utilizing music and rhythm as one of their key game mechanics (e.g., Wii Music [24], Donkey Kong Jungle Beat [25], Beat Saber [2], or Dance Dance Revolution [20]).

In our exergame, the player conducts an entire orchestra at the same time. We use the advantage of VR to make them turn towards the three musician actors in their chair while playing in the VE. Each actor responds to the player individually by increasing the instrument’s volume with each note the player hits correctly. When the player has successfully conducted towards all musicians, they can hear the song with all instruments synchronized (e.g., the “default” version of the song) as a reward. A musician is “completed”
Evaluation was integrated using HDRP. Visual Effects (VFX) Graph with Particle Strips, which allows players to look into the distance and see mountains, the sky, and the sea. Classical and nature settings were favored, so we opted for the concert hall with vintage furniture and a big window. Additionally, they commented on VR experiences of other players and observed how PwD interact with the VE and cope with game mechanics in VR. Based on the information obtained, we aimed to improve the game according to their needs in an iterative HCD process (See Figure 3). Field notes were taken during prototyping sessions. In addition, a caregiver (female, age=51, 26 years of experience with PwD) and a physiotherapist (male, age=40) were asked to provide feedback on the game.

Prototyping Session I. 7 participants attended this session (N=7 female; N=2 mild dementia, N=5 healthy), with an average age of 81.43 (SD=6.66) years. The degree of care for PwD (N=2) was reported as three\(^5\). All of the players were living at HzHG for an average of 4.4 (SD=3.7) years.

All participants played an early version of the conductor exergame under the supervision of the caregiver and our developers. The healthy participants all were in the living room at the same time, so they could watch the other player’s actions on display. Additionally, they commented on VR experiences of other players while sitting together with research assistants at a large table. PwD were in the room individually only with the caregivers and research assistants.

Figure 3: The followed HCD process during the conductor exergame.

The exergame was performed using an i9-9900K CPU and a GeForce RTX2080 Ti graphics card.

3 PROTOTYPING SESSIONS

In the current state of our work, we have held two prototyping sessions at the hospital for older adults. There were both healthy seniors as well as patients with dementia present at these sessions. We observed how PwD interact with the VE and cope with game mechanics in VR. Based on the information obtained, we aimed to improve the game according to their needs in an iterative HCD process (See Figure 3). Field notes were taken during prototyping sessions. In addition, a caregiver (female, age=51, 26 years of experience with PwD) and a physiotherapist (male, age=40) were asked to provide feedback on the game.

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We used the Valve Index VR headset\(^3\), two controllers to act as batons, and an additional HTC\(^4\) Vive tracker and 2 base stations. The player’s in-game view was displayed to spectators and the caregivers on a 65 inch 4k display for two reasons: It gives caregivers enough information to quickly intervene when there is a safety-related issue for the player, and it creates a social environment for everyone involved at that time.

The exergame was performed using an i9-9900K CPU and a GeForce RTX2080 Ti graphics card.

2.2 Technical Setup

The exergame was implemented using C# in Unity3D Game Engine platform (version 2019.3)\(^2\) with the High Definition Rendering Pipeline (HDRP). Visual Effects (VFX) Graph with Particle Strips was integrated using HDRP.

\(^1\)https://unity.com/
\(^2\)https://www.valvesoftware.com/en/index/headset
\(^3\)https://www.vive.com/
\(^4\)The “degree of care” (DoC) is an official term by the German health system, which classifies patients’ degree of independence on a scale of 1-5. E.g., a DoC of 3 means “strong impairment of independence” and is coupled with financial help from the health insurance (https://www.pflege.de/pflegekasse-pflegerecht/pflegegrade/).
everyday routine by resembling the motion of grabbing and moving objects closer or placing them on other surfaces. When holding conversations with multiple people, it is usual to turn towards the person talking. This motion is also reflected by having the PwD rotate their torso towards the different actors and switching their focus during the duration of the exergame.

**Prototyping Session II.** This session was conducted with 4 older adults (N=4 female; N=4 healthy). The average age of the participants was 81.5 (SD=4.66) years. They reported living at HzHG with an average of 5.3 (SD=4.2) years.

In this session, the participants played the current w.i.p. version of the conductor game with the concert hall scenery and virtual tunnel mechanic.

4 FIELD NOTES, OBSERVATIONS, & QUALITATIVE FEEDBACK

Overall, the VR exergame was an enjoyable experience for the players: 6 P2, “What you did there [amazed] [...] it is great, wonderful, music is great [...] I loved it here”, P7, ”[the game] was fun”, and P1, “I liked that very much”.

When we ask the players what they like about the game: P3, “the music, colors, the play of colors is very stimulating”, P5, “the music, [the game is] something completely new, large variety in motions”, P2, “you are crazy, that [the confetti] is great, wonderful”, P7, “It [the game] is great with the stars [confetti]”, and P4, “View was very nice”.

However, some players reported that the physical movements of the game were exhausting, P2, “that [physical movements] would be too exhausting for me”, while for some players, they were not P1, “not really [exhausted]”. Moreover, arm tension was observed in some players during their gaming sessions. Regarding the music preference, the players reported that they would like to hear “Classic, Mozart, Classic Waltz, Vienna Philharmonic” in the game.

The caregiver commented that the game “has an invigorating effect”, however, she found some difficulties in the game for the players “different instructions irritating” and “difficult to notice volume changes”. She stated that the players should perform the movements of the musicians playing their instruments, “the movement should be like drums or [playing] the instrument”. Furthermore, she suggested some music that might be interesting for the players: “Schläger, Roy Black, Costa Cordales, Heino”.

The physiotherapist found the physical movements in the game very helpful for the players “rotating movements are very good, relieves tension”. In addition, he suggested some applicable physical movements, “Two-handed movements are interesting, alternating or simultaneous, to train the weak side as well”, “reaching upward affects the trunk muscles and improves balance”, “increase movement in all directions”, and “pulling strings on a harp itself offers space for various movements”.

Our observations and field notes show that discrepancies between playing music and its associated movement were criticized. The players commented that they did not notice the connection between music/musicians and their movements. Besides, it was seen that the feedback should be more apparent for the player.

5 DISCUSSION & CONCLUSION

By looking at the results of the two focus groups which we already conducted for the VR exergame, we can see that the motions performed by the players seem to be in accordance with the physiotherapist’s opinion. Furthermore, our results suggest that the VR exergame creates motivation for older adults and PwD to perform everyday physical activities in an enjoyable VRE. While this has to be quantified in future studies, the physiotherapist’s subjective visual evaluation and the feedback of the players are a good first indicator for the development of the VR exergame. Moreover, the findings of focus groups imply the necessity of extending the HCD approach by including stakeholders while designing VR exergames for PwD to meet actual everyday life needs of PwD.

Regarding to technical aspects, we aim to improve the immersion and rough calibration of the users by developing custom tracking devices. These allow for the creation of haptic objects in the form of conductor batons, consisting of an Inertial Measurement Unit (IMU) and retro-reflective markers instead of a controller bound to the head-mounted display (HMD). Using two depth cameras with built-in infrared sensors (e.g., Azure Kinect1, Intel RealSense2) the different marker patterns of the tracking modules can be located in space by a combination of depth, acceleration and orientation data. The benefit of standalone tracking modules is increased flexibility during development and a reduced acquisition cost. This enables us to select the appropriate HMD independent of the interaction possibilities, which improves our decision space when determining the appropriate HMD for PwD (E.g. choose an HMD without cable requirements.). Finally, these custom devices are intended to integrate additional users into the game to improve the interaction between players and spectators. They can join the movements on screen, which increases the training effect and reduces downtime for the players.

Currently, we plan to perform future studies on-site at the hospital to further evaluate and improve the VR exergame. Since the initial evaluation revealed multiple issues with the feedback loop and VR immersion, we are also planning to improve the VR staging processes by adding familiarization sequences and pauses for the PwD during the exergame. Next, we plan to conduct a long term (2 months) evaluation study with 10 PwD and regular playing sessions (1-3 times a week). We will evaluate cognitive and physical test scores as well as gaming performance through accuracy and increase in difficulty.

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6 Subscript P shows the participant who played in Prototyping Session I, while P shows the participants who played in Prototyping Session II.

1 https://azure.microsoft.com/en-us/services/kinekt-dk/

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