Design and Evaluation of Virtual Reality Exergames for People Living with Dementia

by

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Author's declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contribution

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Boger, J.	Design and analysis (5%)
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<tr><td>Writing (15%)</td></tr>
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Abstract

Dementias such as Alzheimer's disease are a progressive neurodegenerative disorder with consequences such as cognitive impairment and memory problems. While exercise is important to improve physical health and quality of life for people living with dementia (PWD), symptom-induced challenges, such as language processing and physical limitations, can make it more difficult for PWD to engage in exercise. In this study, exercise games (exergames) to promote exercise for PWD were designed in two virtual environments: a farm and a gym. To design the activities and interfaces of the games, a participatory design approach was followed with exercise therapists, kinesiologists, and PWD from Schlegel Villages long-term care facility. Five upper-body motions were selected and five corresponding activities developed for each game. The games were built for the Oculus Rift CV1 head mounted display virtual reality (HMD-VR) as this platform uses a fully immersive three-dimensional display with high frame rate display. The touch controllers of Oculus were used to provide hand-motion interactions in virtual reality (VR).

A three-week evaluation experiment was conducted with six PWD to evaluate the designed exercise games. A mixed-methods approach was used to qualitatively and quantitatively investigate the impact of using designed HMD-VR exergames in engaging PWD in exercise. Questionnaires for participants recorded participants' feelings of enjoyment, engagement, interest, easiness, comfort, and level of effort. Clinical measurements of fitness parameters and recorded motion parameters from sensors in Oculus Rift provided quantifiable metrics such as range of motion (ROM), distance traversed, speed, grip strength, and shoulder circumduction for evaluation.

All the participants successfully completed the exercise using the exergames, demonstrating the promising potential of using HMD-VR for PWD. The analysis of the participants' answers to the questionnaires shows subjective metrics for human-guided exercise is comparable to VR games conditions, which is a noteworthy result considering the novelty of using VR for PWD. Overall, the analysis of motion parameters showed no differences between environments, which indicates the participants' level of movment in VR environments was as good as with human-lead exercise. This thesis research demonstrates the potential of HMD-VR as an engaging way to support exercise of PWD.

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Finally, I would like to thank Schlegel Villages, especially team members and residents in the Village of Wentworth Heights for all their support in designing and running the experiment and providing such a friendly environment for the days I spent there.

Dedication

This thesis is dedicated to my parents who were there for me my whole life and supported me through my degrees.

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Chapter 1
Introduction

Dementia is a progressive neurodegenerative disorder (Dening & Sandilyan, 2015) that has many consequences, including cognitive impairment, memory problems, functional disabilities, and an overall poor quality of life (Azermai, 2015). Different aspects of life are affected by dementia, such as cognition, behavior, mood, pleasure, interest, gait, and balance.

Longer lifespans and lower birthrates are causing a rapid increase in the average age of people in countries all over the world (World Health Organization, 2017). The global number of people over 60 years of age in 2017 was reported to be 962 million (13% of the entire population), and this number is projected to increase to 2.092 billion by 2050 (21.5% of the entire population) (United Nations, 2017). The prevalence of dementia worldwide is increasing even faster than the aging population with the number of people diagnosed with dementia estimated to be 50 million in 2017 and predicted to increase to 82 million in 2030 and 132 million in 2050 (World Health Organization, 2017).

"Dementia" is an umbrella term used to describe a range of symptoms associated with chronic cognitive impairment. There are several different types of dementia such as Alzheimer's disease, vascular dementia, Lewy body dementia, and frontotemporal dementia (World Health Organization, 2017). Alzheimer's is the most common type, accounting for approximately 60% to 70% of dementia diagnosis and affects short term memory as well as other cognitive and behavior functioning. Dementia is a major cause for dependency and disability of older people and is the 7th leading cause of death (United Nation, 2017).

Dementia interventions may be both pharmacological and non-pharmacological. The pharmacological treatments can have adverse effects, are not always effective, and can be expensive (Fenney & Lee, 2010; Kavirajan & Schneider, 2007). The non-pharmacological treatments can be as or more effective in mitigating dementia symptoms in some cases. Game-based interventions are one example of a non-pharmacological treatment that has shown efficacy in supporting cognitive, behavioral, and physical capabilities (Fenney & Lee, 2010).

1.1 Objectives

Different studies have shown the bidirectional benefits of physical and cognitive health (Loprinzi, Herod, Cardinal, & Noakes, 2013). For neurodegenerative diseases, of which dementia is the most important, considerable evidences suggests that physical activity can slow the progress of disease (Cheng et al., 2014; Gallaway et al., 2017). Despite these benefits, there are challenges such as limited physical abilities and language processing that make persons living with dementia less motivated to exercise.

Virtual reality (VR), refers to the systems presenting a virtual environment. VR systems using head-mounted displays (HMD), have recently received attention from researchers in the healthcare domain as it can provide fully immersive presentation of any environment which can be used in applications such as medical training or rehabilitation. As the fully immersive presentation of HMD-VR makes environments and interactions close to the real world it can help PWD engage in any activity. in virtual environment

The goal of this research is to design, develop, and evaluate a novel, fully immersive VR game to motivate persons living with dementia (PWD) to exercise. Using HMD-VR is expected to help PWD engage in VR-guided exercise that is as effective as human-guided exercise while enjoying playing a game.

1.2 Structure of thesis

The following sections of the thesis are briefly introduced below:

Chapter 2 reviews literature relevant to the project, discussing the role of serious games in health applications specially for people with dementia (PWD);

Chapter 3 details the design process, including all the demonstrations and interactions with specialists and people with dementia in preparing the final design for the experiment;

Chapter 4 elaborates on the experiment procedure and explains the evaluation metrics;

Chapter 5 reports the details of results obtained from questionnaires, observations, and clinical measurement during the experiment;

Chapter 6 discusses the results, and;

Chapter 7 presents conclusions from the research and suggests future research directions.

Chapter 2
Background

In this chapter, the background of the project is presented by explaining the basic concepts, discussing the challenges, and reviewing related works. The first goal of this chapter is to define and clarify some prerequisite concepts used in the next chapters. The second is to review works related to the design of serious computer games for persons living with dementia (PWD) and summaries the main reported findings.

2.1 Benefits of exercise for dementia

Exercise's benefits for different aspects of health for all age groups is well known, with much evidence regarding the impact of physical activity and exercise on physical fitness (Penedo & Dahn, 2005) and cognitive health in particular (Hillman, Erickson, & Kramer, 2008; Kramer & Erickson, 2007). Cognitive and mental health benefit of physical activity is well known fact (morgan2013physical); however, the exact impact of different types of activity on different cognitive functionalities is still the focus of many researchers (Kramer & Erickson, 2007).

Exercise for PWD has been the subject of many studies especially due to its impact on the cognition (Cheng et al., 2014; Littbrand, Stenvall, & Rosendahl, 2011; Loprinzi et al., 2013; Pitkälä et al., 2013; Potter, Ellard, Rees, & Thorogood, 2011). One of the principle reported impacts of exercise for the older adults is its role on mitigating or reducing its cognitive impacts (Gallaway et al., 2017). Physical activity has been reported to play a main role in delaying cognitive decline, which is very important for PWD (Cheng et al., 2014). In general, physical activity and brain health are known to have a bidirectional relation (Loprinzi et al., 2013). A healthy brain regulates the activity in exercise performance, and regular physical activity improves functionalities related to the brain and is important in the prevention and treatment of different neurological conditions (Loprinzi et al., 2013).

Physical activity also has some reported benefits on the social and mental health of PWD (Forbes, Forbes, Blake, Thiessen, & Forbes, 2015). Depression is one of the main mental health issues for PWD. Exercise has been reported to have a positive impact on depression for PWD (Conradsson, Littbrand, Lindelöf, Gustafson, & Rosendahl, 2010; Eggermont, Knol, Hol, Swaab, & Scherder, 2009; Rolland et al., 2007). In one study, 103 participants conducted walking exercise for six weeks while neuropsychological tests, mood questionnaires, and actigraphy data were evaluated before and after the study (Eggermont et al., 2009). The authors (Eggermont et al., 2009) reported that for people attending at least 80% of the sessions, mood improved.

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There is also some evidence that physical activity can improve physical function for PWD (Potter et al., 2011). Many studies have investigated the impact of physical activity on physical function for PWD. A review of 13 related studies with 896 participants employing various exercise programs showed that some of them reported improvement in physical function for PWD (Potter et al., 2011). For example, in one study, 16 participants conducted different exercises that targeted balance, endurance, flexibility, and strength for three weeks and the results showed improvement in fitness parameters such as upper and lower body muscle strength, and balance (Santana-Sosa, Barriopedro, Lopez-Mojares, Pérez, & Lucia, 2008)

Many studies have explored how different exercise types, affect PWD cognitive health in both the real and virtual worlds (Cammisuli, Innocenti, Franzoni, & Pruneti, 2017; Öhman, Savikko, Strandberg, & Pitkälä, 2014). Aerobics are the most well-known exercise type used in the different studies (Cammisuli et al., 2017; Hoffmann et al., 2016; Öhman et al., 2014; G. Zheng, Xia, Zhou, Tao, & Chen, 2016). Zheng et al. systematically reviewed 11 different studies, with 1497 participants in total, in which PWD tried different aerobic exercise programs. Their analysis shows the improvement in global cognitive abilities and immediate and delay recall of memory. For cognitive abilities measurement they used two different metrics: the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975), which is a tool has been used for few decades to systematically assess the mental status, and the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005), which is a well-known cognitive assessment test includes one page questionnaire with 30 marks in total. Moderate and high-intensity physical activity in an aerobic exercise program with 200 patients over 16 weeks was the focus of one such experiment (Hoffmann et al., 2016). The authors reported changes in cognitive performance estimated by Symbol Digit Modalities Test (SDMT) after the intervention, and also change in the ability to perform activities of daily living. The long-term effect of aerobics have also been shown to be positive in improving executive functions for PWD (Cancela, Ayán, Varela, & Seijo, 2016; Heath, Weiler, Gregory, Gill, & Petrella, 2016).

Other physical activities have been used in different studies. Exercise with static bicycles, and resistance exercise using weight vests, weight belts and dumbbells in a four-month study showed cognitive improvement (Brown et al., 2015). Falls and balance problems are important challenges in daily life for PWD. There is a general concern that physical activity may increase the risk of falls (Zieschang et al., 2017); one 12-week study compared the program for two groups of PWD, one with an intensive exercise program and the other with light daily exercise. The group with higher levels of physical activity was safe. Walking in a treadmill for 30 minutes twice a week in a 16 weeks study also showed better cognition level measure by CAMCOG (Arcoverde et al., 2014). Home-based exercise and brisk walks also resulted in improved MMSE for an intervention group compared to a control group in a four-month study with 40 participants (Vreugdenhil, Cannell, Davies, & Razay, 2012). One valuable observation made is that cognitive programs with an exercise program benefit the cognitive abilities of PWD. In (Cheng et al., 2014) Tai Chi, hand crafts and Mahjong were used for different groups of people with cognitive impairment in a 12-week experiment. The participants (totaling 117) did an activity for one hour three times each week. The MMSE improved for the Tai Chi group and Mahjong groups, in comparison to the handicraft group.

Despite of various reports on the benefits of exercise, still some studies have reported no difference in cognitive functions with an exercise program (Pitkälä et al., 2013; Tsai, Chang, Beck, Kuo, & Keefe, 2013). The biochemical markers of physical exercise are also another parameter investigated for PWD (Jensen, Hasselbalch, Waldemar, & Simonsen, 2015).

Considering all the reported benefits of physical exercise for PWD, motivating them to exercise is a great help toward better health condition. This was one motivation for this study.

2.2 Challenges of exercise for dementia

Despite several studies showing the benefits of exercise, as discussed in the previous section, there are some challenges in exercise programs for PWD, mostly arising from their limited or impaired cognitive and physical abilities(Dobbs et al., 2005; Pitkälä et al., 2013; van Alphen, Hortobágyi, & van Heuvelen, 2016). These challenges usually negatively impact the level of engagement in exercise for PWD.

A general challenge common to both PWD and all older adults is the change in physical abilities; however, the limited abilities of PWD stem from both aging and the result of cognitive impairment. Alphen et al. (2016) reviewed and listed different barriers in physical exercise for PWD. Some barriers are related to physical health such as risk of falls during the exercise (Malthouse & Fox, 2014) and impaired body function (Cedervall, Torres, & Åberg, 2015). Some other barriers are related to mental health such as problems with orientation abilities (Cedervall et al., 2015), and problems with attention and memory (Yu & Kolanowski, 2009). Disliking structured exercise is another challenge for PWD which makes them less motivated to attend exercise programs in long-term care (Suttanon, Hill, Said, Byrne, & Dodd, 2012).There are also some barriers from the physical environment that makes attending an exercise program challenging for PWD, especially when they need to leave their home or residency. Difficulties in finding the way (Cedervall & Åberg, 2010), fear of being away from home (Suttanon et al., 2012), dedicated space and storage issues (Dal Bello-Haas, O'Connell, Morgan, & Crossley, 2014), and bad weather (Malthouse & Fox, 2014) are some examples of barriers related to the physical environment for the physical activity of PWD.

Another challenge in encouraging exercise in PWD comes from language processing problems, which interfere with understanding the exercise instructions in group setting programs. The overall effects of language processing problems and difficulties with social communications reduce PWD confidence in attending exercise programs, especially in group settings.

2.3 Serious games

The primary goal of games is usually entertainment. The term "serious games", however, refers to any game that has a primary goal other than entertainment (Bergeron, 2006). The elements of a serious game, such as actions, characters, tasks and environments, are similar to those in the other games, but the main goal of users performing the activities is not entertainment (Deterding, Dixon, Khaled, & Nacke, 2011). In other words, serious games can be seen as a way of applying "gamification*",* which is defined as "using game design elements in non-game contexts" (Deterding et al., 2011). However, the boundaries of these concepts are still not clearly defined (Deterding et al., 2011). Serious games have been used in different applications such as general education(Michael & Chen, 2005; Van Eck, 2006), language training(Lewis & others, 2010), health(Burns, Webb, Durkin, & Hickie, 2010; Kayali et al., 2015), services (Roenker, Cissell, Ball, Wadley, & Edwards, 2003), and the military (Lim & Jung, 2013), and has been referred to by different names such as pervasive games (Montola, Stenros, & Waern, 2009), alternate reality games (Bakio\uglu, 2015), and playful design (Ferrara, 2012).

2.4 Serious games for persons living with dementia

Serious games are widely used in health domain (Lager & Bremberg, 2005; Sawyer, 2008) for applications such as medical training, mental health, and physical rehabilitation (Burns et al., 2010; Graafland, Schraagen, & Schijven, 2012; Kayali et al., 2015; Rego, Moreira, & Reis, 2010; Schönauer, Pintaric, Kaufmann, Jansen-Kosterink, & Vollenbroek-Hutten, 2011). There are many research studies that have used serious games for supporting PWD (McCallum & Boletsis, 2013; J. Zheng, Chen, & Yu, 2017).

McCallum et al. reviewed dementia related serious games and discussed the reported benefits of these games for PWD (McCallum & Boletsis, 2013). They concluded that based on the experimental results of different works, dementia games (games designed for PWD) have a positive cognitive impact, however, there is still a need to investigate the long-term impact of these games. This will deepen the field’s understanding of the cognitive benefit of video games (Green & Bavelier, 2006) as well as the long-term impact concern worth to study based on the studies show the long-term impact of games for older adults (Willis et al., 2006).

Based on the taxonomy suggested in (McCallum & Boletsis, 2013), the games for PWD can be categorized based on their goal into three groups: 1) Games for physical health, 2) games for cognitive health, and 3) games for social emotional health. The memory enhancement is a well-known reported benefit of cognitive training with games (Mahncke et al., 2006), while other aspect related to quality of life and social emotional health such as social exchange with games has also been the topic of some studies for older adults (Keyani, Hsieh, Mutlu, Easterday, & Forlizzi, 2005). In addition to the health benefits of games for PWD, they have also designed and used for the detection of dementia (Bayo-Monton, Fernandez-Llatas, Garca-Gomez, & Traver, 2011; Tong & Chignell, 2014; Tong, Chignell, Tierney, & Lee, 2016; Vallejo et al., 2017). In one study, the response time to a cognitive task has been shown to be in direct correlation with the standard ways to determine cognitive level of a person (Tong

& Chignell, 2014). In next, I first introduce the technologies and devices used in different studies for running games for PWD and then review examples of games designed for PWD.

In computerized games, a user interacts with a simulated environment, which is also known as virtual reality (VR). The hardware setup for playing a computerized game includes a personal computer to generate the game environment, a display device for visualization, and a game control device to provide interaction for the user. The most common displays are computer monitors, wall-based projectors, and TVs (McEwen, Taillon-Hobson, Bilodeau, Sveistrup, & Finestone, 2014a; Moyle, Jones, Dwan, & Petrovich, 2017; Stavros, Fotini, & Magda, 2010; Tárraga et al., 2006); however, with the advances of new technology, head-mounted displays (HMD), which provide fully immersive display and better feeling of presence, are becoming affordable and a more popular display option for game play (Mendez, Joshi, & Jimenez, 2015). There are several different types of input control device that can be used. A computer keyboard and mouse have been used in some studies (Mccallum & Boletsis, 2013; Stavros et al., 2010), while touch screens have been used to make interactions in games more interesting (Manera et al., 2015; Tyack & Camic, 2017), as well as new game controllers, such as Nintendo Wii (Fenney & Lee, 2010; Padala et al., 2012; Weybright, Dattilo, Rusch, & others, 2010). Gloves or other motion sensors have been used in few cases to capture movements close to daily life and provide more flexibility in the types of motions that can be captured; however, they have been customized based on the design and difficult to generalize to other games (Yamaguchi, Maki, & Takahashi, 2011).

There is a growing number of games that have been developed and used for PWD. In (Fenney & Lee, 2010), a virtual bowling game with Nintendo Wii was used in a nine-week training program with a five to six months follow-up for three participants living with dementia. All participants improved their bowling scores and memory functioning. Another study designed and used a sport video game based on brain-activating rehabilitation (BAR) to simulate physical activity for both upper and lower limbs. For the upper body they implemented capturing a virtual coin with virtual hands controlled by customized sensors mounted on participants' hands to control interactions, and a flat screen TV to display the virtual coins. For lower limb physical activity, participants tapped feet on a mat with a sensor installed on it to simulate the motions from two Japanese drums. The target of game task was creating physical activity, and the results measured by Hasegawa's Dementia Scale-revised (HDS-R) showed improved cognitive levels in all 9 participants (Yamaguchi et al., 2011). Wii-Fit, as a virtual exercise game, has been used in another study in comparison to a real-world walking program (Padala et al., 2012). Twenty-two participants in two groups, followed an eight-week program of 5 days of exercise in each week. The Berg Balance Scale (BBS), Tinetti Test (TT), and Time Up and Go (TUG) were used as physical and cognitive tests for evaluation. The final results showed more general improvement in cognition and gait and balance; however, the BBS and TT showed significant benefits in the Wii-Fit group.

Kitchen and cooking is another serious game developed based on a European project named VERVE (Manera et al., 2015) to stimulate executive functions such as planning abilities for PWD. For the project, 21 persons with Mild Cognitive Impairment (MCI) or early stage dementia were hired for a one-month trial with one session per week. The game was displayed on a tablet and participants were free to play the game as long as they wanted. To evaluate the game's impact, self-reported questionnaires were used to assess participants' overall game experience (including acceptability, motivation and perceived emotions). Game performance was measured by using parameters such as time spent playing and number of errors. Based on results, both the kitchen and cooking activities engaged participants. In another study (Rendon et al., 2012), a Wii-based VR cognitive game was used over a six-week experiment with 40 participants. The participants worked with the game three times each week, and the results show improvement in the VR group versus. a control group (who did not play any games) as evaluated by the 8-foot Up & Go test and Active-specific Balance Confidence Scale. In a comprehensive analysis of the feasibility of using VR for PWD, researchers investigated the experience of PWD interacting with a virtual environment, assessing parameters such as presence, user inputs, display quality, simulation fidelity, and overall system usability. For this analysis, six participants performed four functional activities such as mailing letter in a virtual outdoor park. The physical and psychological well-being of participants in interactions with VE were assessed by measuring their heart rates. The overall results of this study show that PWD experienced presence and found objects realistic and moved naturally. Difficulties in using a joystick were reported in this study (Flynn et al., 2003).

Navigation and path finding in a city are important daily tasks that are challenging for some PWD, which can reduce their outdoor activities. As result, they may experience decreased quality of life and accelerated progress of dementia (Ott et al., 2008; Teipel et al., 2016; Zakzanis, Quintin, Graham, & Mraz, 2009). One experiment compered the functionality of participants walking in a real city with when they were walking in a virtual city, to investigate beneficial parameters to help these people live independently (Blackman, Van Schaik, & Martyr, 2007). The study noted the benefits of using textual signs to help wayfinding and to identify objects and places in the environments.

Memory abilities have been investigated for PWD in interaction with VR-based vs. therapist-led training programs. In an experiment with 24 participants in 10 sessions of 30 minutes each, the multifactorial memory questionnaire and Fluid Object Memory Evaluation assessed participant performance in two environments: a home setting and a convenience store one. The results showed improved memory functionalities, however, VR training showed better objective improvement.

VR games have been used for PWD for cognitive assessment purposes as well. One such assessment simulated the interviews in a virtual environment (Mendez et al., 2015). The answers of five participants were recorded during interviews with an avatar, and their heart rates were also monitored. They also subjectively expressed their stress level after the interview. The VR-based interviews were shown to be comparable to real-world interviews, and participants produced greater verbal elaboration when answering in virtual reality.

A distinct class of games designed for PWD have targeted exercise (G. Zheng et al., 2016). In one study, PWD activity in a virtual environment has been investigated by simulating five activities in VR: soccer, snowboarding, birds and ball, formula racing, and juggling (McEwen, Taillon-Hobson, Bilodeau, Sveistrup, & Finestone, 2014b). The two-week experiment had two goals: 1) investigating the feasibility and safety of exercise programs in VR, and 2) the effect of exercise on balance and mobility. The evaluation of the impact of these activities was based on clinical balance and mobility measures, before, during, and after the training program. They also obtained qualitative feedback by interviewing participants and caregivers after intervention. They concluded that the VR exercise program was safe, feasible, and enjoyable for PWD; however, there were no significant improvements in balance and mobility. The researchers proposed that was because of a confounding effect on motor function due to cognitive impairment, however, it may also be because of a limited sample size and short intervention period.

The reported outcomes of the reviewed studies in this section show the potential of serious games for cognitive stimulation and physical function improvement. Serious games usually make for interesting environments for these people, but the design and activity selection needs to be performed carefully. While HMD VR provides a greater presence in the virtual environment and makes it more realistic and interesting, an existing gap in the research is a lack of using fully immersive HMD VR technologies for exercise that is specifically designed for PWD.

2.5 The potential of Virtual Reality exergames for PWD

The current best-practice solution for the challenges of exercise for PWD mentioned in the previous section is holding one-on-one exercise sessions with exercise therapists. However, due to limited human resources and costs, this solution is rarely adopted. Designing serious games with the goal of supporting exercise (exergame) could help to overcome these limitations.

Considering the challenges faced by PWD, exercises that use VR have some advantages over human-guided exercise. The first advantage is that VR enables activities that are difficult or impossible for a PWD to experience in the real world. For example, in a VR game a person with dementia can row a boat along a scenic river or go deer hunting with a rifle in the forest. The second advantage of exercise in VR is that the distances and sizes of objects in virtual environment can be customized based on the range of motion of each person. Another advantage is that interactions in VR are usually safer than real world because all objects are virtual. VR also makes it possible to quantitatively measure the activity and range of motions of players, which might be used for tracking progress or clinical assessments. Virtual environments are endlessly customizable for relatively low-cost.

In the reviewed studies about using VR exergame for PWD, the impacts of exergames were investigated mostly on cognitive functioning and/or the balance of users. However, there is a lack of research on engagement and encouragement of PWD in exercise in the literature. In this research, I designed, developed and evaluated some VR exergames to promote physical activity for PWD.

Using VR exergames played using a HMD provides a fully immersive simulation of three-dimensional games. It gives a better sense of presence in the game environment to the person who is using it, which is important for engagement (Dow, Mehta, Harmon, MacIntyre, & Mateas, 2007). My thesis work involved the co-design of novel HMD-VR exergames to encourage engaging in exercise for PWD.

In selecting the stimuli and activities in the design process for PWD, their history and interests play an important role in their engagement in game (Cohen-Mansfield, Thein, Dakheel-Ali, & Marx, 2010; Hanten et al., 2011; Leone et al., 2012). To obtain this knowledge, in this study the design process performed with collaboration with both experts in long-term cares and PWD as it is also recommended for any design for PWD (Hendriks, Truyen, & Duval, 2013).

2.6 Concerns and challenges in designing HMD-VR exergames for PWD

Despite potential benefits of developing an HMD-VR exergame for PWD to motivate exercise, there are challenges and concerns that must be addressed.

A primary concern in introducing and applying HMD-VR as a new technology for PWD is whether they feel comfortable using this technology. Due to cognitive impairment and having limited familiarity with recent technology, it was not clear if participants would be comfortable with using an HMD and watching a simulated environment that they have to interact at the same time. Similar challenges come with using a hand controllers or sensor in capturing their motions. Selecting proper device in terms of safety and comfort is very important for PWD.

Motion sickness is one of the reported side effects of using HMD-VR. Motion sickness usually comes from incompatibilities in human perception of object locations and their motions in virtual reality vs. the real world. However, recent advances in building HMD has resulted in higher resolution images and higher refresh rates, thus making more-realistic environments and motions. Still, this issue remains an important challenge in many applications and is of especial concern for PWD as their sensory perception may be impaired, which could exacerbate motion sickness.

To engage PWD to exercise, selecting proper activities and environments is important. To achieve this goal, user abilities and preference should be considered in design. This is not possible unless the game developers have access to and incorporate the lived experience of PWD; one way to achieve this is through participatory design.

Chapter 3
Participatory design process

This chapter discusses the participatory design process that was used to develop the VR exergame for dementia prototype. The process of design has been participatory in collaboration with kinesiologists, exercise therapists and persons with dementia. Ethical approval was applied for and obtained from the University of Waterloo prior to starting the participatory design process.

3.1 Focus group

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 2):

> "The first step in the process was to gain an understanding of the abilities, preferences, and needs of the intended users (i.e., PWD). I began by reviewing the user-centered design literature for guidelines regarding developing technology for PWD. In addition to common usability principles for the general population (Nielsen, 1994; Norman, 2013), I also consulted principles for older users (Pernice & Nielsen, 2008; Wolfson, Cavanagh, & Kraiger, 2014). A guiding premise is that the interface should be designed to be as simple and intuitive as possible to minimize users' cognitive workload on attention, comprehension, and memory, as these are generally impaired for older adults. For example, in the 3D virtual world, visual objects should be high-contrast, large enough to be easily seen, and placed in front of the user in the central field of view. However, as demonstrated in previous chapter, there is a lack of literature focusing on PWD. Regardless, it is imperative for us as the designers to have first-hand knowledge of the characteristics and limitations of PWD.
>
> I and my supervisors attended the semi-annual recreational planning meeting held with 25 kinesiologists, exercise therapists, and recreational therapists from Schlegel Villages—a Canadian organization that manages 19 long-term care and retirement communities across Ontario. At the meeting, we presented the idea of HMD-VR and its use to engage PWD. In general, they found the idea interesting; however, they also had a few concerns about the feasibility. For example, would PWD feel comfortable wearing the HMD? Would they feel disoriented during the transition between different VR scenes and between VR and the real world? Could they learn how to use the hand controllers to interact with virtual objects?

Nevertheless, the caregivers were generally supportive. It was one of the attendees who suggested using HMD-VR to support exercise. It was also through this meeting that we met our exercise therapist team member, who collaborated with us extensively as a member of the core design team throughout the project.”

3.2 Shadowing Observation

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 3):

“I and both my supervisors each conducted an eight-hour shadowing observation session in a long-term care center of Schlegel Villages. I and one of my supervisors had no previous experience designing with people with dementia. The goal was to gain first-hand experience about the life of people with dementia. During the sessions, the authors talked with the residents and participated in their activities such as walking, watching TV, and serving meals.”

3.2.1 Observations and lessons

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 3):

“It was observed that most residents had very limited physical activities. Although there were events planned for them such as singing, Tai Chi, puzzle solving, and towel folding, many residents sat and watched TV for much of the time. Many residents were also social and engaged when we interacted with them, which lent support to our expectation that the residents might enjoy VR programs if the programs can be designed properly for them to use.”

3.3 Second focus group

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 4):

“After the shadowing observations, the next stage involved a focus group meeting, where we brought an HMD-VR system (Oculus Rift CV1) and two existing VR programs for eight kinesiologists and PWD to try. The first program (Through the Ages: President Obama Celebrates America's National Parks) is a 360-degree VR movie that plays videos recorded from a national park. The second program (NVIDIA VR Funhouse) is a virtual carnival game with small games such as slicing balloons, whack-a-mole, and shooting plates, which require the use of hand controllers."

3.3.1 Lessons learned and feedback

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 4):

"Kinesiologists, therapists, and three residents with dementia tried using both VR programs; all of them could interact with the programs. This positive result helped improve our understanding of how PWD might react to HMD-VR and increased the research team's confidence. Valuable feedback was obtained from the discussion that followed.

A kinesiologist commented that playing fighting games might agitate residents who had previous aggression issues. This suggested that calm activities should be used in the design. Another kinesiologist commented that hand gestures and buttons on the hand controllers were not very intuitive to learn and use. This device limitation suggested that the design should avoid interaction that requires specific gestures or pressing buttons. For safety reasons, I also decided that all users should play the VR programs while seated to avoid the risk of falling. This seating requirement is the same as the practice at Schlegel Villages for therapist-guided exercise."

3.4 First iteration of design and testing

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 4):

"In designing VR exergame, I collaborated with kinesiologists and exercise therapists in Schlegel Villages to carefully select appropriate motions, environment, and tasks. In this step, one of the exercise therapists from Schlegel Villages was interested to the project and joined the research group as a co-designer of the games. This was very useful as using the experience of an exercise therapists ensured the game was more appropriate both for people with dementia and for achieving exercise goals. In the following sections, the selection of exercise, environments, and activates are reported."

3.4.1 Exercise selection

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 3):

> "As I decided on a seated posture for safety and avoid risk of participants falling, the motions used in the exercise were limited to the upper body (i.e., neck, arms, and torso). Finger motions were excluded to increase simplicity and to allow users to keep holding the controllers in both hands in the VR scenarios. Applying these constraints, the exercise therapist on our team consulted with her therapist colleagues to select motions from the ones used in existing therapist-guided exercise. Five motions were selected to match the game scenario: 1) head rotation, 2) reaching straight ahead, 3) cross-body reaching, 4) lifting both arms, and 5) rowing with both hands."

3.4.1.1 Head rotation

The following text has been copied from our publication (Boger, Eisapour, Domenicucci, & Cao, 2017, p1):

> "The neck flexion and extension exercise have the person move his or her head in the vertical and horizontal planes, activating the neck muscles. Incorporating these movements allows for the muscles associated with and around the pectoral girdle to be sufficiently warmed up prior to engaging in the rest of the exercises."

3.4.1.2 Arm movements

The following text has been copied from our publication (Boger, Eisapour, Domenicucci, & Cao, 2017, p1):

> "The ability to reach is vital to the independent completion of a range of activities, including leisure, mobility, and self-care. Ideally, reaching requires arm mobility in all directions, which can be improved through flexion and abduction/adduction exercises. Exercising the shoulders can improve arm range of motion, strength, and contribute to fall recovery capabilities."

3.4.2 Environment selection

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

> “Regarding the environment to implement the motions, we followed the therapists’ recommendation to use a calm place that is enjoyable for most residents. The place should be a common daily life location where the planned motions can be implemented as intuitive, meaningful, and interesting activities. We considered a kitchen, a farm, a pet store, and a gym. Through many discussions with therapists, the farm was selected as it is familiar and interesting for most of the residents, is gender-neutral, and has a variety of activities that can be simulated”.

The pet store was not selected as it is somewhat similar to farm, most of the interactions with animals can be also simulated in farm, and some actions (e.g., rowing) would be difficult to simulate in a pet store environment. The kitchen was not chosen as it was felt fewer people would be interested in activities in kitchen compared to a farm.

The gym was also selected as another virtual environment in our design to mimic the environment of common human-guided exercise program in the long-term care. Similar to farm, a gym is gender neutral and familiar for all participants. The gym provides a cross-over environment where the delivery of the exercise is more similar to the human-guided approach, which enables us to investigate the delivery of exercise using VR itself separately from a completely different environment and delivery modality (i.e., farm environment). Using these two selected environments, participants performed two completely different environments, enabling the investigation of the impact of different virtual environments on participants’ engagement in exercise.

3.4.3 Activities selection

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

> “I with my supervisors, and the exercise therapist in our research team composed a list of candidate activities that were plausible to do in a farm and focus on upper body motions. The candidates included watching butterflies, picking flowers, grabbing fruits, turning wheels, painting fences, lifting piles of hay, and sorting various objects. Following the simplicity principle, we decided to only present a minimal number of objects in each activity to reduce cognitive workload also we decided to add a few objects in the background to help with context and orientation. For example, most of the tasks should have only one interactive object in the scene. If selection was needed, no more than two options should be presented. In the end, the selected activities included butterfly watching (for head and neck turning), sorting apples and

oranges into baskets (for arm reaching straight and across body), lifting a large object such as a box or a pile of hay onto a stand (for lifting with both arms)."

The details of selected activities for the farm will be explained in this section. For the virtual gym, the same motions would be guided by an avatar that participant need to repeat the same actions based on instruction given.

The following text has been copied from our publication (Boger, Eisapour, Domenicucci, & Cao, 2017, p 1):

"The head rotation in farm was elicited through VR by a butterfly flying in a circular path with audio instructions to look for the butterfly, as depicted in **Error! Reference source not found.**. Motions are repeated three times in each direction (clockwise and counter-clockwise)."

Figure 1. Following a butterfly in virtual farm environment as an activity designed for neck rotation (reproduced from Eisapour, Cao, Domenicucci, & Boger, 2018).

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"For the first prototype, three exergames were developed to elicit three different arm movements that had been identified by the exercise therapists: reaching straight ahead, cross-body reaching, and overhead reaching. Straight ahead and cross-body reaching exergames were based on a sorting task where the participant picked apples and oranges from the ground in two sides and placed them into baskets filled with the corresponding fruit. In the straight ahead reaching exergame, participants picked up apples on the virtual "ground" in front and slightly to their left using their left hand and place them into a basket of apples placed ahead and slightly to their left;

the same was done with oranges slightly to the right, as shown in Figure 2. For cross-body reaching, the fruits were placed on the "ground" further to the side of the participant and the corresponding basket was located to the front and on the opposite side, as shown in Figure 3. The overhead reaching exergame involved participants lifting boxes filled with apples from the "ground" in front of them onto a cart, as shown in Figure 4."

Figure 2. Fruit sorting activity designed in virtual farm environment for reaching straight ahead motion (reproduced from Eisapour et al., 2018).

Figure 3. Fruit sorting activity designed in virtual farm environment for cross-body reaching motion (reproduced from Eisapour et al., 2018).

Figure 4. Lifting boxes filled with apples activity designed in virtual farm environment for overhead reaching motion (reproduced from Eisapour et al., 2018).

3.4.4 First prototype demo

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 5):

> "In collaboration with the exercise therapist on our team, I developed our first prototype HMD-VR exergame program. We presented the initial prototype to a group of six kinesiologists/recreational therapists and four residents with mild-to-moderate dementia at Schlegel Villages for their comments and feedback."

3.4.4.1 Lesson learned and feedback

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 5):

> "In a short verbal interview with participants after trying the exergame, they responded positively and enjoyed all of the activities. The kinesiologists commented that they were pleasantly surprised to see the level of engagement and degree of motion elicited by playing the game.
>
> This preliminary testing was extremely valuable as it found several areas that could be improved and enabled in-person discussions with therapists and residents regarding how to go about improving them. For example, a pile of hay was initially used as the object in the object lifting task, but some residents had difficulty in finding an appropriate way to grab and lift it with

both hands. After discussion, we decided to use a box instead and place two obvious handles on the ends to signal the places for holding it. Another example of improvement suggested by kinesiologists was adding another movement to the program. Kinesiologists suggested to add a rowing movement. Rowing has been established as an exercise that improves cardiovascular and shoulder health strengthening the core and contributing to better posture. The movements involved with rowing a boat incorporate repeated squeezing and stretching shoulder blades. It was decided to present rowing as the final exergame as it is the most vigorous of the exercises.

One important issue that arose was the need for individual calibration. For example, in the apple sorting task, there was a considerable difference in residents' range of motion (ROM) capabilities. Customized object location is needed to avoid frustration, enable people to achieve their goals, and ensure that every user can benefit from an appropriate level of stretching."

3.5 Second Iteration of Design and Testing

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"Based on feedback from therapists and PWD in the first iteration of design and testing, we revised the design and developed the second prototype. In this step, we added the calibration initialization program and also adjusted some activities. We ran another demo after these modifications."

3.5.1 Calibration

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"This is particularly important for older adults, who may have conditions that limit ROM (e.g., stroke, arthritis). Moreover, limitations in ROM may not be bi-lateral; a person may have significantly more ROM on one side than the other.

During the calibration task, each user tried to reach targets (apples) presented at increasing intervals of distance along different directions (Figure 5). The ROM limit was recorded as a parameter for each individual person. This parameter was then used to automatically adjust object locations in the exergame with the activities calibrated to 80% of each individual's ROM limit to ensure that the exergame was well within their abilities."

Figure 5. Calibration setup includes picking apples located in different distances in four directions to obtain users' range of motion.

3.5.2 Updated activities

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"After the first iteration of design and testing, I applied some adjustments to the design and activities.

One of the modifications was replacing the hay object in the reach overhead activity with a box of apples and placing two obvious handles on the ends of the box to signal the places for holding it.

We also added rowing activity. The rowing exergame had the participant seated in a virtual boat in a small lake with the oars visible in front of them, as shown in Figure 6. Virtually touching an oar "attaches" it to their hand, after which they can move about the lake as they wish. Clouds in the sky, trees along the shore, hills, beaches, and rocks were strategically placed in the background to provide interest and environmental cues without overwhelming the participants."

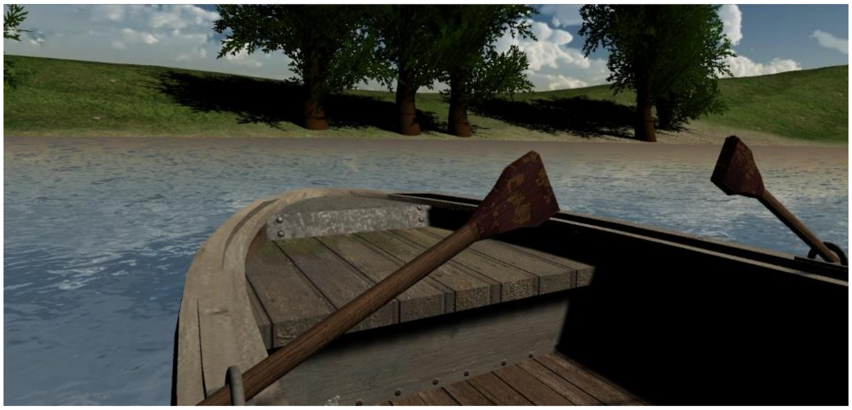


Figure 6. Rowing activity implemented in virtual farm environment for rowing motion (reproduced from Eisapour et al., 2018).

3.5.3 Second Prototype Demo

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

> “The second prototype was tested with three PWD using an Oculus Rift CV1, which has a resolution of 1080 by 1200 pixels per eye at 90 frames per second. A digital video camera was used to record participants’ interaction with the program. During the test, participants were seated in a chair to avoid falling, and sufficient space was provided to avoid any collisions while using the HMD (Figure 7).

Figure 7. A person using HMD device and playing game.

An LCD monitor was used to mirror the participants' view inside the HMD for researchers in the same room to see and control the task procedures and detect any problems. The location of the test was at the Village of Wentworth Heights, which is a Schlegel Village long-term care/retirement home in Hamilton, Ontario, Canada. All tests were supervised by two trained therapists to ensure the safety and wellbeing of participants. All three participants with dementia were naive to VR and the tasks. Participants each did the calibration task before trying the five exergame scenarios.

The three PWD who participated in testing of the second prototype were able to follow the butterfly; many reached out to touch it as well. Watching PWD doing the exercise prompted the exercise therapists to suggest that perhaps a "T" pattern would be more effective. We incorporated this into the next version.

The three residents who participated in the pilot tests were all able to do the reaching exercises. The apple and orange sorting exercises were particularly effective. The box-lifting task gave some trouble as the handles were hard to see; plans were made to modify the handles of the box so that they were easier to see (i.e., greater contrast) and the top of the cart (i.e., the 'target') is lowered a bit to ensure it is in the field of view so people know where they are to place the box.

The rowboat game was the most engaging for the three pilot testers in our study. All three could row and the task naturally was adapted to their individual capabilities. In all three cases, the researchers ended the task as the maximum allotted time was reached."

3.5.3.1 Lesson learned

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"The calibration worked well, making objects reachable and close to the ROM limit for each person. In general, the response was very positive. All three participants could complete all the exergame tasks. In fact, therapists commented that the game was eliciting greater ROM than they thought some of the participants were capable of. While some were hesitant to try the HMD-VR, participants clearly enjoyed using it (e.g., smiling, laughing, and in one case, singing), including the calibration task."

3.5.3.2 Users' feedback

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"All scenarios were engaging and enjoyable for the participants. For example, one of the participants seeing the apples in the calibration procedure said, "Oh wow, it's good! Can I take a bite of the apple?" Another participant, when she found herself in the boat rowing scenario, said "Oh, I am in a rowboat!" and started singing. For all three participants, the test was ended by the researchers (as we set a 15-minute time limit) rather than by the participants."

3.5.3.3 Experts recommendations

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"Some feedback was obtained from therapists after our second demo. For example, it was recommended to add more background objects such as trees and barns, which could help participants to orient and better understand that they are on a farm. In the butterfly watching task, it was recommended to add the calibration of both the range and speed of the butterfly's movement, accommodating people with different head and neck ROM. In the box lifting task, the height of the wagon should be adjusted so that participants can see the top of it, which can serve as a natural cue for the target location. The handles on the boxes should be larger and use a more salient color. In the boat rowing scenario, a recommendation was to add water sound. It was also recommended to add vibration on hand controllers as feedback to inform the completion of an action. We applied these valuable recommendations in the final version of our design for the experiment."

3.6 Design considerations for persons with dementia

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018a, p 6):

"Through our participatory design process creating an exergame, I have identified the following HMD-VR design considerations for persons with dementia.

- Keep visual targets within the front field of view. Avoid searching that requires head motion.
- Provide verbal prompts before the transition between real world and VR, as well as the transition between different VR scenes.
- Provide verbal instructions that bring users into the scene and task, in a gentle, casual, and story-telling fashion.
- Avoid using buttons or gestures as control input. When moving objects, directly attach objects to the hand when it is reached, and directly remove objects from the hand at target locations.
- Use high contrast and tasks that implicitly signify how to interact with objects (e.g., salient handles that indicate where to grab and hold).
- Use a calibration process to adjust the required range of motion for each individual; this ensures an accessible and engaging experience.

- Prevent errors, enable exploration of the game space in a supportive fashion, and clearly indicate when a task has been successfully accomplished.

Consult specialists and get feedback from PWD; participatory design process helps identify hidden problems and improve the quality of the VR program for the target users.

Interacting with virtual objects without using any buttons on control interface is highly recommended for these populations to not to exceed their workload capacity. In addition, since these people have various range of motions and functional ability, flexible design to apply customized distances and controls for each individual is vital."

Chapter 4

Empirical study evaluating the HMD-VR exergame for people living with dementia: Method

In this chapter, the details of the experiment conducted to evaluate the designed exergames is discussed. The participants hired for experiment, the HMD used for running the game, and the procedure followed in the experiment are discussed first and then the evaluation methods considered for this study are introduced.

4.1 Participants

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018b, p 3):

> “Eight participants were recruited from SV’s Wentworth Heights location in Hamilton, Ontario, Canada. After the consent procedure the MoCA test (as explained in section 2.1) was administered to assess the cognitive level of the participants. One of the participants decided not to participate and another declined to continue after the first day of the trials. The other six participants (one male and five females) completed the study. The average age of the participants was 86.8 ± 6.2, and their average MoCA score was 17.5 ± 2.1. The MoCA score for each participant is reported in Table 2; a MoCA score below 18 is considered mid-stage dementia.”

The participant who declined to continue after the first day of trial did not like the location of the testing room and chose to withdraw from the study; they did not mention any negative perspectives regarding the technology or study goals.

We recruited our participants based on the following inclusion and exclusion criteria:

Inclusion criteria

- 60 years and older
- able to communicate verbally in English
- at least four years of education (as required by the Montreal Cognitive Assessment (MoCA))
- score between 18 to 25 on the MoCA

- at level 1(independent transfer) or level 2 (one-person transfer) on the Transfer Status Assessment Guide

Exclusion criteria

- moderate or severe cognitive impairment (as identified by the Schlegel Village neighborhood coordinator)
- prone to motion sickness
- has hearing impairment that may interfere with the ability to understand verbal instructions
- any pre-existing conditions that would preclude the exercise activity that advised by neighborhood coordinator or exercise therapist
- a history of epilepsy and/or seizures
- having a pacemaker

Following the inclusion and exclusion criteria and recruitment protocol, every effort was made to avoid bias in participant recruitment and to ensure participants were representative of the general population of PWD in Schlegel Villages; however, as the sample size was small, it cannot be proven definitively and needs more investigation with larger groups of participants in future work.

4.2 Devices and tools

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018b, p 2):

> "This research used an Oculus Rift CV1 as the HMD-VR device as it has low weight, high refresh rate of 90 frame per second for each display, and a horizontal field of view of 110 degrees (Figure 8). For running the experiment, a personal computer with 12GB of RAM, running Windows 7, and the graphic card of NVIDIA GTX 970 was used. For interacting with virtual objects, Oculus touch controllers were used, but only reach and contact actions were required (no button pressing). Figure 7 shows a participant using HMD and hand controllers interacting with a virtual rowboat in the designed environment. For the design of 3D environments, Unity 3D game engine version 5.6 was used. Avatar's motions in the gym environment have been generated by motion capture of human actions using Microsoft Kinect for Xbox 360."

Figure 8. The Oculus Rift CV1 device used in the experiment which includes head mounted display (HMD), motion sensors, and touch controllers (248am.com, n.d.).

4.3 Procedure

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018b, p 3):

> "A week before starting the experiment, the participants were asked to attend a short training session to become familiar with the VR system and to perform a calibration task for their range of motion. For training, the Oculus Rift HMD and sample virtual environments were introduced. During calibration, participants' range of motion in four directions including left, right, up, and front was measured by a task of reaching virtual apples in each direction (Figure 5).
>
> The evaluation phase consisted of three weeks of trials. The participants started with one week of human-guided exercise with a professional exercise therapist from SV. In the second week, they worked with one of the two VR environments, and for the third week they switched to the other VR environment. In the virtual gym, participants were asked to mimic an avatar's actions. In the farm environment, participants performed activities related to farm tasks. All three scenarios used the same motions in the same order and with the same number of repetitions. The order of presentation of VR environments was randomized and balanced across the participants.

In each of the three weeks, participants performed the tasks targeted for that week for five days, where each session of a day was within 20 minutes. In each session, all five selected motions were conducted either in a real-world human guided manner or in the interaction with virtual environment.

The therapist recorded instructions for each of the VR scenarios to guide users in each task. For safety concerns, the participants were seated in a wheelchair during each session to avoid falling, while at the same time an exercise therapist was in the experiment room during all sessions. All sessions were video recorded for future analysis by the research team. The experiment was conducted in the same room in the long-term care facility for all three weeks."

4.4 Evaluation methods

Different subjective and quantitative evaluation methods were applied in this study to assess the success of design in encouraging PWD to engage in exercise. The subjective analysis was done through a combination of data from the questionnaires for participants and kinesiologists and recording observations by the exercise therapist. The quantitative analysis includes both clinical measurements and recorded track of hand and head positions from the device's sensors. In this section, we will discuss these analyses in more detail.

4.4.1 Participant questionnaire

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018b, p 3):

"Two questionnaires were used to subjectively compare the capture the perceptions of the participants; one was administered after each session (i.e., every day) and a second was used after finishing each week (i.e., after each scenario)."

To design these questionnaires, we consulted with the exercise therapist in our team and considered the main goals of engagement in exercise. "Questions were designed to be clear, direct, and understandable by PWD

The following text has been copied from our publication (Eisapour, Cao, Domenicucci, & Boger, 2018b, p 3):

"In the daily questionnaire, after performing their session participants were asked about their enjoyment and feeling of having enough of a workout. For enjoyment, a 5-point Likert scale question was used while two-point (yes/no) question was asked about workout (see Appendix A for a copy of questionnaire). In the weekly questionnaire, participants were asked to evaluate the engagement and enjoyment level of the scenario they just tried. In these questionnaires, our goal was to capture the participants' feelings of comfort, level of difficulty, engagement, and interest in the scenario of the week (see Appendix B). In addition to these evaluations, we also asked participants if they wanted to continue the scenario to evaluate their motivation after one week of the scenario."

The participants' responses to the questions in these questionnaires were used after the experiment to ascertain feelings of the participants about working with the designed game. Statistical analysis (repeated measures ANOVA) of the responses in each condition was used to reflect the possible preference of participants with respect to one condition versus another.

4.4.2 Participant interview

To gain a deeper and new insights about how participants perceived engaging in VR-led exercise, we asked some open-ended questions after each session and also each activity. The participants' responses then were recorded.

After each session in each day, we asked the following question from each user in the interview and discussed about their feedback if there was any point.

- Is there anything else about this session that you want to share with us today?

The participants were also asked some questions in the interview at the end of each week to obtain their feedback regarding the activity of that week and in comparison, to the previous week(s). The following is the list of questions we asked from the participants in the after-activity interview:

- What is the exercise that you found easiest? What made it easy for you?
- Is there any exercise you found hard?
- Is there any exercise you found more interesting?
- Is there any exercise you found less interesting?

- What about the equipment? Did you find comfortable using the head mounted display and the hand controllers?
- Anything that made them comfortable?
- Anything else that you want to share with use about exercise this week?

I left participant free to talk if he/she wants about any aspects of experiment or feeling about the experiment in the interviews.

The feedback from the participants in the interviews is reported to illustrate comments made during the trials and to gain a better understanding of responses to the questionnaires.

4.4.3 Clinical physical assessment

To look at the impact of our exercise program on participants' physical range of motion, we used two standard clinical measurements of ROM after each activity (at the end of each week): the SFFA test (Appendix D), and shoulder circumduction protocol (Appendix E), both of which are standard physical measurements in assessing older adults' ROM and are used in Schlegel Villages.

SFFA is a measurement for head, arm, and grip strength (see Appendix D). The parameters in this test and the measurement methods are listed below:

- Height: Participant stands with heels together, bum and shoulders against the wall and height is measured by a tape.
- Head-to-wall: The distance of participant's head to wall in the normal standing position. Resident presses shoulders and sacrum into wall. Be sure there is no chin retraction and bottom of ear and eye are on same plane. Measure distance from occiput to wall.
- Reach downward: This task looks at the participants' ability to reach down and pick up an object from the floor. User starts from standing position and being asked to reach down to pick up a dowel as close to the floor as possible and the distance of fingers to the floor is measured in the pickup position.
- Reach upward right/left arm: This task looks at the ability of participants to reach for objects on a shelf. While participant stands with the side of his/her foot against the wall, we ask

him/her to reach as high as possible while maintaining a straight arm. The height of the fingers is measured in this state for both right and left arm.

- Grip strength: This task measures participant's hand grip strength. This task is performed using a dynamometer. Two measurements are taken for each hand.

To assess the shoulder flexibility a shoulder circumduction test was conducted. In this task, we measured the length of acromion, shoulder circumduction, and the difference by using a flexible measuring tape (Figure 9). The details of the test are explained in Appendix E.

The clinical measurements introduced in this section are used to measure physical abilities in the fitness of the participants. The statistical analysis of numbers obtained for each of the measurements during the experiment reflect the physical function of participants between conditions. As the intervention was so short, there is unlikely to be any improvement.

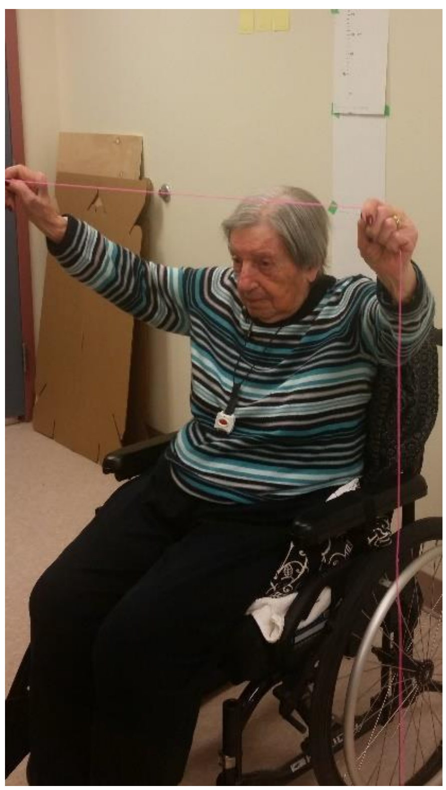


Figure 9. A participant performing shoulder circumduction test.

4.4.4 Kinesiologist questionnaire

Following the completion of the experiment we consulted kinesiologists from Schlegel Villages from across Ontario to find their opinions about our developed exergames and identify directions for future work. In this meeting we asked the attendees to use the farm scenario and fill out a questionnaire 0). 11 kinesiologists volunteered to try the farm game and shared their thoughts through the questionnaire. The feedback collected from kinesiologists is discussed in details in the next chapter. I will report the kinesiologists' comments on my design to see whether the design is compatible with their expectation in general or not and if the proper exercises have been selected for this study or not.

4.4.5 Motion analysis using sensor data

One of the advantage of VR exergames using the Oculus headset and touch controllers over the human guided exercise is the possibility of collecting objective quantitative motion data from the sensors while the participants is performing an action in the VEs. Metrics such as speed and range of motion can be calculated using the recorded data, which could be used for new quantitative analyses of a person's exercise performance and fitness.

In this study, we tracked the position of both hands and the head from Oculus Rift HMD and touch controllers in the VR activities. We also used the sensors to record track of participants' motion in the human-guided week by having them hold the hand controllers to enable a comparison of the performance from all three weeks. As the track is recorded in each task of each session, I performed an analysis of the participants' workout across different days, different tasks, and different environments; these results are presented in the next chapter.

The motion parameters were used to statistically compare the exercise level of different conditions (human-guided, gym, and farm). Any significant differences between the values obtained from the measurements of these parameters can show the possibility of involving these people in the exercise in the preferred condition. Statistical tests and the results are reported in the next chapter.

4.4.6 Evaluating the success of design

To evaluate the success of designed HMD-VR exercise program, the main research questions in the study should be considered. The main research questions in this study are if PWD can exercise with HMD-VR and will be any subjective or objective measurement show the preference of exercise using

HMD-VR to the human-guided exercise? The evaluation methods explained in previous sections could help to assess the success of the designed exergame as an answer to these research questions.

One aspect can show the success of this study would be completion of exercise by HMD-VR by participants and interacting with environment. The analysis of reported level of subjective parameters such as enjoyment, easiness, interest also show if VR can work as good as human-guided or even better than that in case of users feeling about exercise in these environments. The quantitative analysis of motion parameter or clinical measurement can also reflect if the engagement in exercise in VR were comparable or even better than human guided or not. If the VR is comparable or better in this analysis, this would be another success for the project.

Chapter 5

Empirical study evaluating the HMD-VR exergame for people living with dementia: Results

As discussed in the previous chapter, different tools were used to assess the design and the experiment in motivating the PWD persons to do more exercise, including questionnaires, clinical measurements, exercise therapists feedback, track data analysis, and participants' general feedback. This chapter reports the results obtained from these evaluations. A structured qualitative analysis of the results is beyond the scope of this thesis; therefore, subjective evaluations were done for qualitative data. Sample feedback from participants is also reported in this chapter.

5.1 Participant questionnaire

One of the factors that we evaluated in the daily questionnaire was enjoyment. Each participant scored their level of enjoyment of the session that day using the 5-point Likert scale question "How much did you enjoy the session?". The average scores for the three environments are plotted in Figure 10.

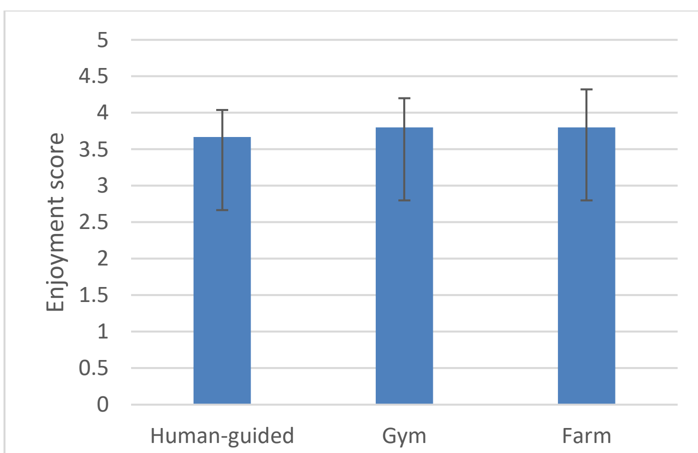


Figure 10. Participants' self-rated level of enjoyment from daily activities in three environments measured by 5-point Likert scales with SD error bars, where 5 is "loved it" and 1 is "hate it". Error bars represent the standard deviation of scores in each environment (reproduced from Eisapour et al., 2018).

As it can be seen in Figure 10, overall enjoyment of participants from the two virtual environments (3.80) is comparable to human-guided week (3.67); the difference between the conditions is not statistically significant (repeated measures ANOVA, $F(2,10) = 0.727$, $p = 0.507$, $\eta_p^2 = 0.127$).

To evaluate the participants' satisfaction with the amount of physical activity, we used a yes/no question that asked, "Do you feel you got a good workout from this session?" The results of average feeling for each week and for each of the six participants reported in Table 1. Four of the participants felt that they had enough exercise in three environments; however, participants 2 and 6 had different opinions and preferences.

Table 1. Participants' MoCA test score and perceptions regarding enough of a workout in each session. Session scores obtained from daily questionnaire where 1=yes and 0=no.

Participant ID	MoCA score	Human-guided	Farm	Gym
1	15	1	1	1
2	15	1	0.4	0.8
3	19	1	1	1
4	18	1	1	1
5	18	1	1	1
6	20	0.4	0.9	1
Average	**17.5**	**0.9**	**0.88**	**0.97**

In the weekly after-scenario questionnaire, we used 5-point Likert scale questions to evaluate the participants' feeling of comfort, easiness, engagement, and interest in each environment. The average scores for each of these four factors are reported in Figure 11 for the three environments.

As it can be seen in Figure 11, the overall levels of ease of the tasks in the farm and gym environments were similar (both 4.17) and higher than the human-guided condition (3.6); however, the difference was not statistically significant (repeated measures ANOVA, $F(2,8) = 2.364$, $p = 0.156$, $\eta_p^2 = 0.371$).

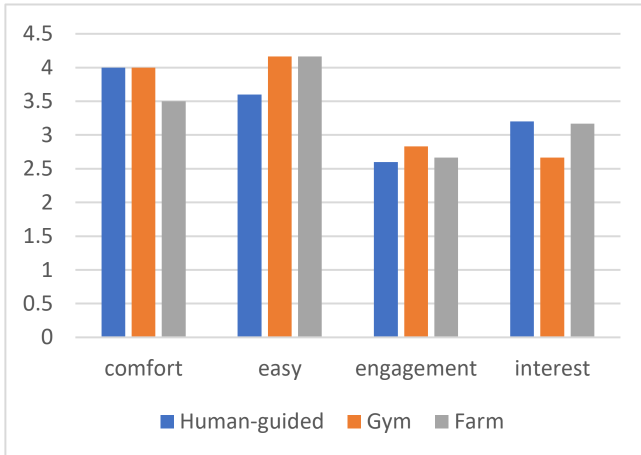


Figure 11. Participants' responses in the after-scenario questionnaire to evaluate four different quality measures. The comfort, easiness and interest are measured in 5-point scale which 5 means "strongly agree" and 1 means "strongly disagree". The engagement level was measured with a 4-point scale with 4 for "extremely engaged" and 1 is "not engaged at all"(reproduced from Eisapour, Cao, Domenicucci, & Boger, 2018).

In the after-scenario questionnaire administered each week, we asked participants about their motivation to continue working with the scenario they were just doing in that week. All the participants reported being motivated to continue for all scenarios with the exception of one participant who would not want to continue with the farm scenario.

5.2 Participant interview

From the short interview was conducted after each session different comments were obtained from different participants.

One feedback from participants was about their enjoyment of using with virtual environments. For example, one of the participants expressed her enjoyment by:

P4: "*I love looking at the blue sky, the sky and switching the apples and rowing a boat which I really wasn't, yeah, look like that I was moving*"

The rowing activity in the virtual lake was relaxing for them while they knew they are doing exercise.

P1: "*I love rowing because it was relaxing, you know, when you are relaxing you are exercising*"

P1: "*Good for everyone. rowing relaxing*"

They also expressed their general feeling of enjoying the VR designs.

P1: "*I enjoy[it] very much.*"

P6: "*Too easy. Engaging environment*"

Other feedback was about their perceived progress. One of the participants enjoyed her exercising and she felt she could do longer sessions.

P6: "*It was a longer class today, rowing, ... I could [keep] going*"

Or another participant felt she could do actions faster.

P4: "*I think I could grab them fast, faster than what I did this before, I could do it because I didn't realize that I could pick them even though there is lighter ... it's slider, that's ok*"

One of the participant who had phobia of being in the lake was engaging of the rowing and tried the design more and more every day.

P4: "*I haven't been on water for a long time, so I don't know, but it's not bad, we can keep trying*"

They also were positive about the goal of this exercise program. When one of the member of research team asked a participant is there any exercise that she thinks was not interesting she answered.

P4: "*No, I think they are all necessary*"

Another participant was positive about the mental impact of the designed activities.

P4: "*That was nice. that's test for mental.*

The first one [human-guided week] was for physical, this one [farm week] was for mental."

Participants also reported some points which can be used to improve or extend the study and design. For example, one of the participants to have more variety of actions instead of repeating some actions.

P2: "*Too much repetition. more motion needed. everything was the same.*"

Another participant would prefer more of a challenge:

P6: "*wish it would be more challenging.*"

or more repetition of activities to get more exercise:

P4: "*There wasn't that many apples*"

However, others felt the task complexity if good enough, so one way to improve is to consider different level of cognitive involvement in the task to be chosen for participants based on their cognitive ability and/or their preference. The goal-based activity was important for a participant.

P6: "*it would be nice to know that there is a goal to reach"*

P6: "it's difficult to row to get nothing"

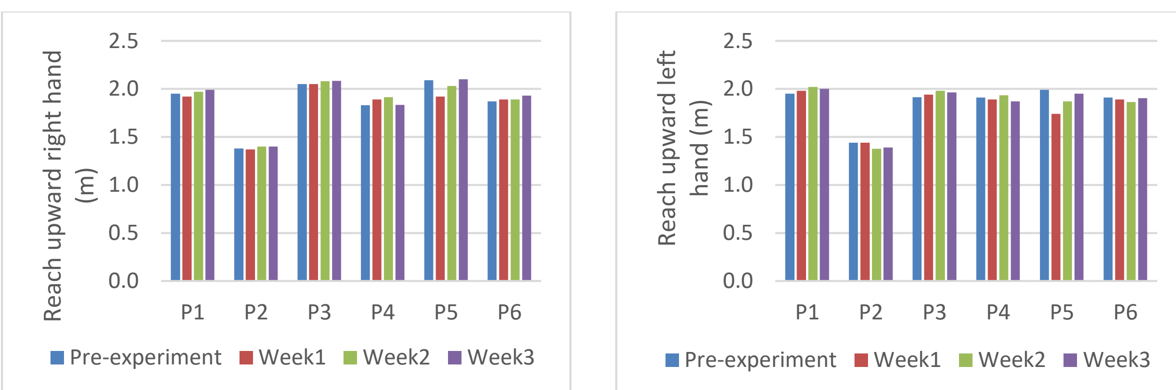
The speed and type of controls and action was also important for some of them.

P4: "*I missed a few cues [instructions] sometimes.*"

P4: "*The woman [the avatar in gym] ..., sometimes she goes too slow, sometimes she stops, then starts, I didn't want to stop, am I supposed to be following her direction?*"

5.3 Clinical physical assessment

Using the clinical measurements explained in 4.4.3 and by applying both SFFA and shoulder circumduction, we conducted these measurements in four different steps including pre-experiment, after week 1, after week 2, and after week 3. Table 2 summarizes the measurements for all six participants. To evaluate the impact of activity in each week on physical metrics reported in Table 2, I compared reach overhead, shoulder circumduction, and grip strength of participant in each step in Figure 12, Figure 13, and Figure 14 respectively. In these figures, week 1 represents human-guided exercise while week 2 represents gym exercise for three participants and farm exercise for the other three participants. In week 3, participants switched environments, meaning that those who worked with the gym environment in week 2 worked with the games in farm for week 3 and vice versa.



(a) (b)

Figure 12. Reaching upward for both right(a) and left(b) hand for all six participants using a single measurement at the end of each week

Table 2: Clinical measurements of each participant. (Pre: Pre-experiment, H: Human, G: Gym, F: Farm).

Participant ID	Condition (Env.)	Height (cm)	Head to wall (cm)	Reach downward (cm)	Reach upward (Right arm) (cm)	Reach upward (Left arm) (cm)	Grip right 1 (lb)	Grip right 2 (lb)	Grip left 1 (lb)	Grip left 2 (lb)	Acromion (cm)	Circumduction (cm)	Diff. Circ. And Accr. (cm)
1	Pre	162.0	0.0	0.0	195.0	195.0	27.0	25.0	30.0	27.0	34.0	153.0	119.0
	H	162.0	0.0	0.0	192.0	198.0	29.0	30.0	25.0	30.0	34.0	153.0	119.0
	F	162.5	0.0	0.0	197.0	202.0	28.0	31.0	31.0	33.0	34.0	136.0	102.0
	G	160.0	0.0	0.0	199.0	200.0	29.0	27.0	29.0	29.0	34.0	148.0	114.0
2	Pre	143.0	21.5	8.0	138.0	144.0	10.0	10.0	9.0	11.0	32.0	88.0	56.0
	H	146.0	19.5	6.0	137.0	144.0	10.0	12.0	5.0	12.0	32.0	58.0	26.0
	G	145.5	20.0	17.0	140.0	137.5	6.0	4.0	2.0	4.0	32.0	80.0	48.0
	F	145.0	22.0	5.0	140.0	139.0	8.0	6.0	3.0	5.0	32.0	103.5	71.5
3	Pre	167.0	1.0	1.0	205.0	191.5	70.0	72.0	60.0	58.0	34.0	163.0	129.0
	H	168.5	2.0	4.0	205.0	194.0	66.0	62.0	59.0	55.0	34.0	148.0	114.0
	F	166.5	0.0	1.0	208.0	198.0	66.0	62.0	53.0	58.0	34.0	145.0	111.0
	G	168.2	0.0	4.0	208.5	196.5	71.0	62.0	58.0	51.0	34.0	142.5	108.5
4	Pre	154.0	0.0	0.0	183.0	191.0	22.5	19.0	16.0	17.0	33.0	144.0	111.0
	H	155.0	0.0	0.0	189.0	189.0	18.0	19.0	10.0	9.0	33.0	125.0	92.0
	G	153.0	0.0	0.0	191.5	193.5	23.0	22.0	19.0	15.0	33.0	136.0	103.0
	F	153.0	0.0	0.0	183.5	187.0	26.0	21.0	15.0	16.0	33.0	134.0	101.0
5	Pre	173.0	0.0	0.0	209.0	199.0	40.0	40.0	42.0	43.0	35.0	134.0	99.0
	H	171.5	0.0	0.0	192.0	174.0	30.0	29.0	41.0	44.0	35.0	107.5	72.5
	F	173.0	0.0	3.0	203.0	187.0	41.0	39.0	36.0	39.0	35.0	103.5	68.5
	G	171.5	0.0	0.0	210.0	195.0	40.0	35.0	45.0	31.0	35.0	125.5	90.5
6	Pre	152.5	0.0	0.0	187.0	191.0	35.0	30.0	25.0	23.0	32.0	124.0	92.0
	H	153.0	0.0	0.0	189.0	189.0	32.0	35.0	31.0	26.0	32.0	128.0	96.0
	G	152.5	0.0	0.0	189.0	186.5	30.0	32.0	24.0	22.0	32.0	124.0	92.0
	F	152.0	0.0	0.0	193.0	190.5	30.0	30.0	23.0	21.0	32.0	129.5	97.5

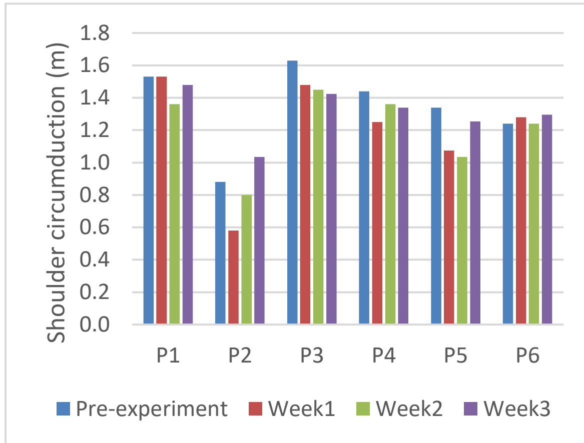


Figure 13. Shoulder circumduction for all six participants for each week.

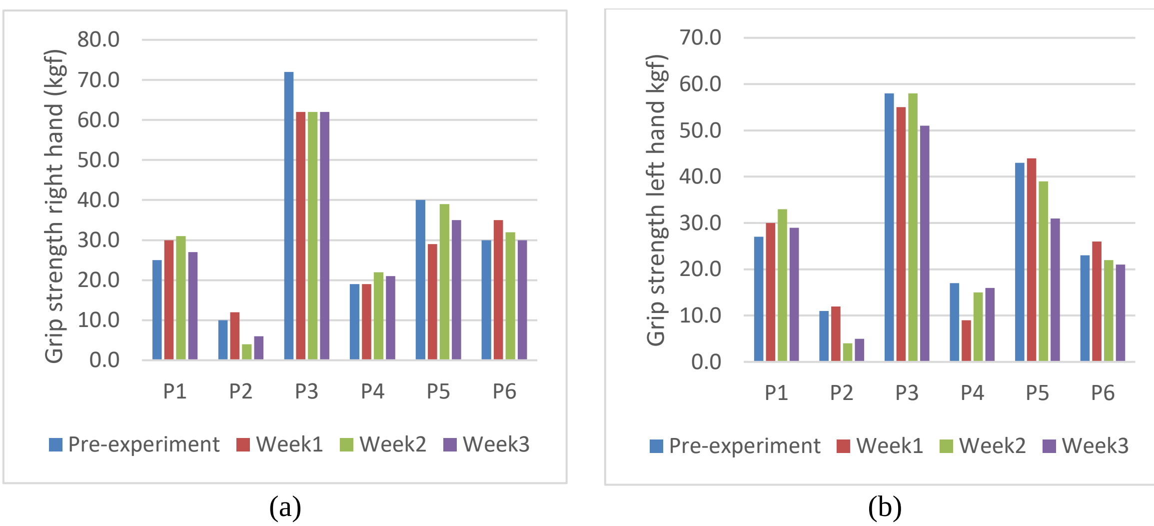


Figure 14. Grip strength for all six participants for each week for right hand (a) and left hand (b).

From Figure 12, it can be observed that reach upward appear to remain the same across weeks for each participant and has not been affected to much with the conditions. Shoulder circumduction as reported in Figure 13 appears to have no better for most of the participants at the end of experiment compared to the first week. From Figure 14, it can be observed that there is no visible trend in the measurements of grip strength for different participants.

5.4 Exercise therapist observation

The professional exercise therapist on the research team, who also helped in running the exercise sessions, recorded her observations for each session. This feedback is summarized in this section and includes observations on participants, comments on challenging parts of the design or the procedure, and some suggestions for improvements.

She reported evidence of high levels of engagement and presence for participants in the virtual environment. For example, she made the following comments:

"*[one of the participants] talks to the system and answers it*"

"*[Another participants after the first day] immediately grasped the oars and started rowing without waiting for the instructions*"

One participant engaged and

"*Verbalized what butterfly was doing and followed butterfly*"

Another participant

"Performs the tasks on point"

Based on her observations, participants showed good progress in doing the task of each activity after the first day.

"*[one of them] rowed longer today and seemed less frustrated*"

"*for a participant who had problem in the first day) … got first basket immediately; keeps putting hands too narrow but today did aim for top*"

She also believes that based on their reactions in working in VR environments and performing exercise task, the design were successful in providing enjoyable activity with the actual goal of getting them exercise more:

"*Interesting to see that most residents do not recognize the parity of the movements between the three environments; furthermore, they don't consider this exercise*"

There were only a few reports of minor dizziness or motion sickness related problems during all sessions of the three-weeks of experiment, which were less than what was reported in other researches.

“*Feeling a bit dizzy after removing the HMD*”

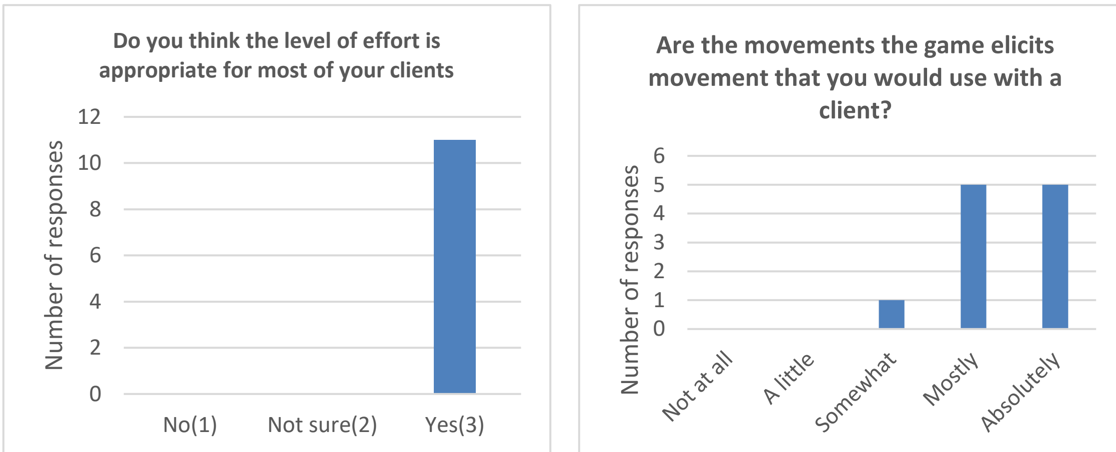
“*Slightly nauseated but declined need to rest a few minutes*”

Some other points were also mentioned in the exercise therapist feedback that we listed below:

- Some participants might not hear properly, so it is better to check sound level with them before playing the game. One of the participants had troubles hearing and asked to go louder;
- Although we locked the wheel chair and marked the location to keep the setup fixed, the position of chair was changed for one participant in a session while she was seating. This position change made a little shift in the location of objects. We can find a more robust ways to fix chair.
- Despite the pre-training session to make participants familiar with the touch controllers, some participants were trying to catch fruits by hand at the first tries of the first day, however they quickly used the device. In the training sessions, we can add more game to make sure they will easily work with the device.
- We had an unpredicted distraction of PA system in long-term care building which distracted a participant in one of the sessions. Any distraction from the environment should be avoided.

5.5 Kinesiologist questionnaire

As explained in section 4.4.4, an evaluation was conducted with kinesiologists in a dedicated session where they tried out the farm scenario and completed a questionnaire (0). In the kinesiologists’ feedback form, the first two questions quantitatively measured the kinesiologists’ opinion about the appropriateness of the type and level of exercises considered in this study. Figure 15 reports the results from their answers by showing the number of participants selected each option in the multiple-choice questions.



(a) (b)

Figure 15. Kinesiologists' feedback on the appropriateness of the level (a) and type (b) of exercise and movements selected in this study (n= 11).

From the feedback on Q3 regarding the suggested motion to add to the design, one of suggestion was mentioned multiple times was lower body motion that could be performed in the seated position. Different stretching activities was also suggested by some kinesiologists as answer to the Q3. They also proposed implementing other daily life activities. Some other suggestions were pronation, supination, hair brushing, boxing, and marching. These activities could be considered for future extension of this study is discussed in Chapter 7.

As the potential of tracking the position of hand and head during the exercise with HMD-VR is an advantage of using VR exergame, an important question is what would be the possible usage of such data. We asked kinesiologists about the possible use of such data for informing the exercises for PWD and/or to monitor their ability to perform exercise. The most mentioned metric was range of motion (ROM), such as how far people are able to move their hand or head. Some other interesting parameters that have been mentioned to be valuable to measure from the track of hand and head were speed, smoothness of motions, delay in start, number of repetition, and distance traversed by participants. Seated balance and progress of actions such as reach were the other parameters mentioned.

In the answers to Question 5 of feedback form about mentioning the aspects kinesiologists feel using VR for exercise does well; many interesting aspects were mentioned. The presence in an outdoor environment and engagement in virtual environment were the most important aspect mentioned by kinesiologists in this survey. One of the kinesiologists said:

"I really like that it is outdoor environment. I enjoyed looking around while rowing, it makes you forget you are in a room"

Another one said:

"[VR] Allows residents to really feel like they are out of the village. These is limitless potential in VR."

Another quote was:

"*The experience was quite realistic*"

Another aspect of using VR mentioned in response to Q5 in this questionnaire was the distraction from the main goal of the activity (exercise) while you are in a virtual environment. This also supports the presence and feeling of doing an interesting activity while the participant involved with having exercise. Some quotes from kinesiologist are

"*You are having fun, don't realize you are moving*",

or

"*… environment doesn't make it feel like exercise …*".

Using the goal-based activities was another aspect mentioned. Although it is not specific for VR exergames but VR provides safe environment for many activities possible in the real life for these people. A kinesiologist says:

"*Turning exercise into more meaningful activities making movements more functional for a resident*"

One of the important aspect was significant for kinesiologists was the possibility of emulating different environments and the ability of VR to provide interaction in such environments in a safe and controlled environment.

Based on the experience of kinesiologists in working with interactive VR environments we designed for this study, they suggested some improvement as answer to the question 6 in their feedback form. Following is a short list of the main improvements mentioned by the 11 kinesiologists:

- Adding more activities from real-life,
- Modifying calibration speed,

- Increasing the level of instruction sound,
- Adding more object to follow in the neck movement practice, and
- Adding lower body motions in seated position, and
- Adding bicycle tour.

In overall, all kinesiologists were positive about the designed exergame program with HMD-VR and they enjoyed our design and activity selection. For example, one of the kinesiologist really enjoyed the rowing environment:

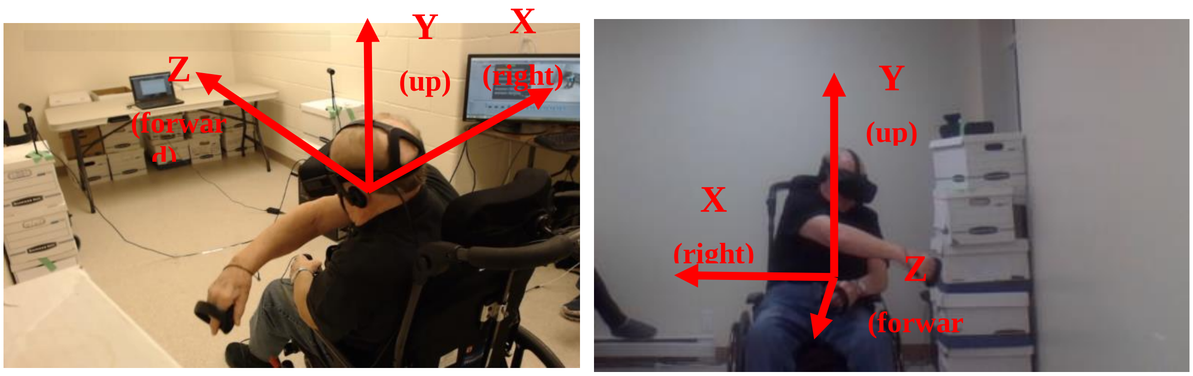
"*Amazing start. The boat scene was calming and enjoyable*."

5.6 Motion analysis using sensor data

The position of hand and head from touch controllers and HMD sensors was captured at each moment (with the rate of 90 samples per second) during each activity. These data can be used to investigate the parameters of motion in each activity such as range of motion, speed, and distance traversed. This section reports the analysis of the captured data. First, we introduce the coordinated system and the targeted direction in each activity and then we report numerical results and plots extracted from data.

5.6.1 Directions and coordinate system

Depending on the activity, the targeted motion is usually in one or two directions. For simplicity of pointing to different directions in result analysis, we represent the three-dimensional space of experiment room with three axes of x, y, and z which represents left-right, up-down, forward-backward directions respectively. Figure 16 shows a participant working with VR system in the experiment room and the three axes. The user is considered as the center of the world in this coordinate space and the positive directions are right, up, and forward for relative to the user for x, y, and z direction. Figure 16 shows a participant working with the design and the directions of all three axes related to the participant.



a) Participant's view from back b) Participant's view from front

Figure 16. Three-dimensional coordinate system used in the analysis of motions captured by sensor have been shown in both view of back and front for a participant.

5.6.2 Major directions of motion

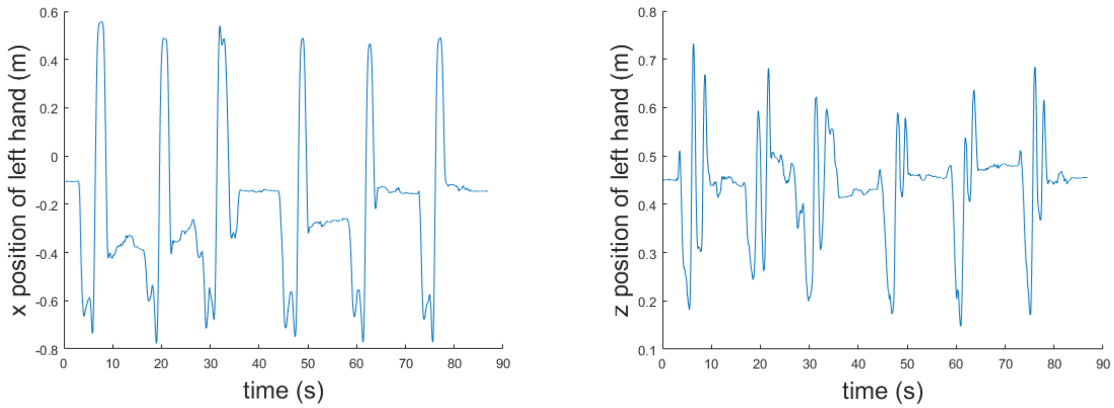
Based on the coordinates system defined in Figure 16, I summarized the major directions of motion of each activity as indicated in Table 3

Table 3. Major directions of motion for each activity.

	Targeted direction				
	Hand and shoulder movement			Neck rotation	
Activity	Left-right (x direction)	Up-down (y direction)	Forward-backward (z-direction)	Yaw	Pitch
Neck rotation				x	x
Lift overhead		x	x		
Reach forward straight	x		x		
Reach forward cross	x		x		
Rowing		x	x		

5.6.3 Spatial track of sensor data

The record of track of motion is performed in each iteration of refreshing the displays at 90Hz. Recording the position of hand/head in each moment of an activity, I track hand/head throughout the entire activity. **Figure 17** shows an example track of the left hand for a user performing the reach forward-across activity.



(a) (b)

Figure 17. Example position data for a participant from the of left hand for the reach forward-across activity

From the captured data, we can plot the 2D track of hand spatial domain as shown in Figure 18.

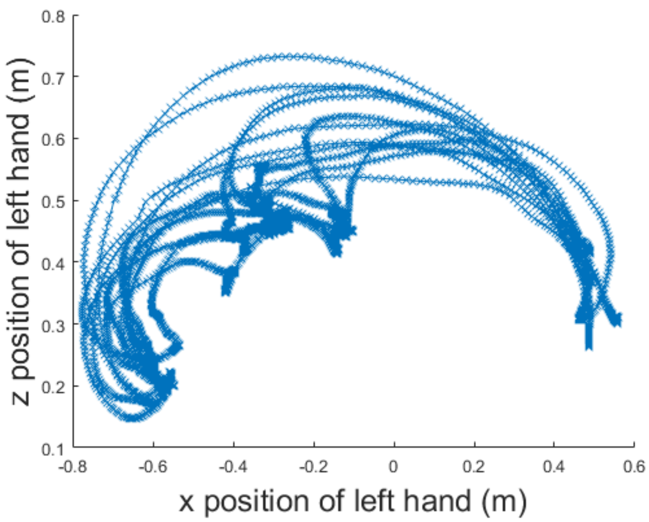


Figure 18. Two-dimensional position of the left hand for a sample reach cross activity of reach forward-across.

From the recorded position of head and hand during each activity, we can extract different metrics to evaluate participants' movement. These metrics and their measurement are discussed in the following sections.

5.6.4 Metrics measurement: Range of Motion (ROM)

One parameter that can be extracted from the track of hand and head is range of motion (ROM). The ROM in general is defined as the distance that an object or part can move when it is attached to another part. This distance can be measure in linear or angular space. In this study, ROM is defined as the distance of movement of hand or rotation of neck in a direction. ROM of a user in an activity in a specific direction is defined as the distance between extreme points (max and min of coordinate) in that direction that the participant could reach during the activity. Figure 19 shows schematically how we measured range of motion of a participant in a sample activity based on the 2D track reported in Figure 18.

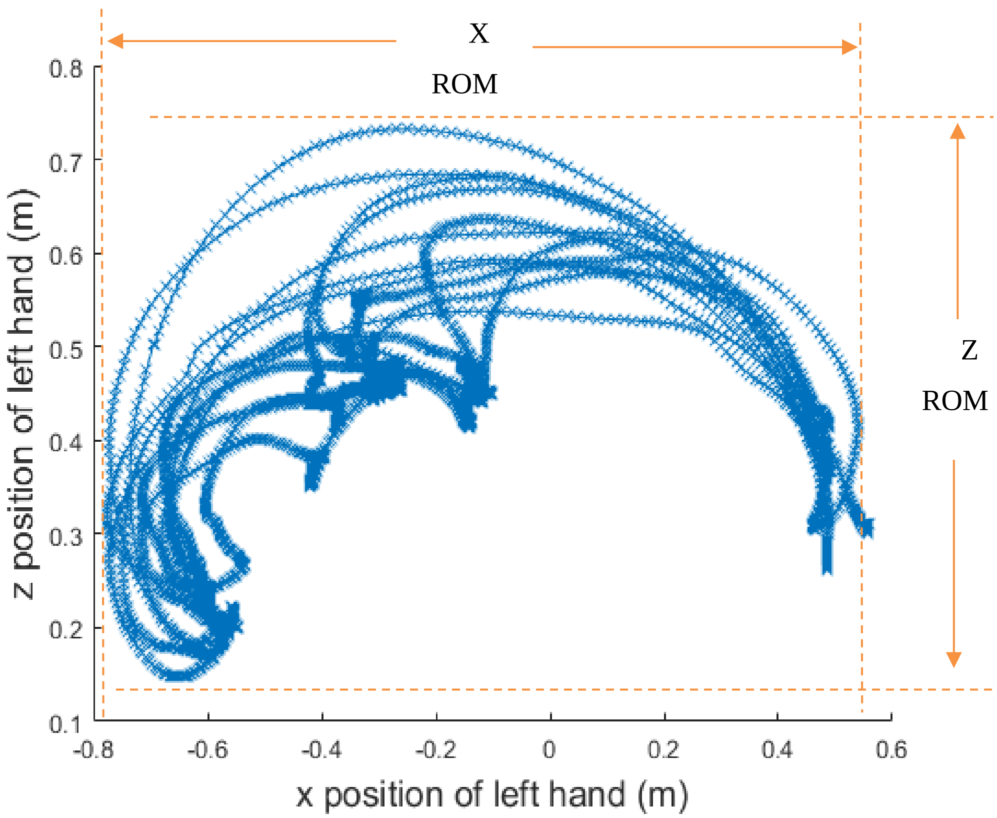


Figure 19. Range of motion in x and z directions based on the track of motions recorded from reach straight cross activity.

Figure 20 to Figure 23 show the range of motion of each participant in each day of three weeks of experiment (Human guided, Gym, and Farm) for different activities. The details of numerical values are reported for the reference in Appendix G.

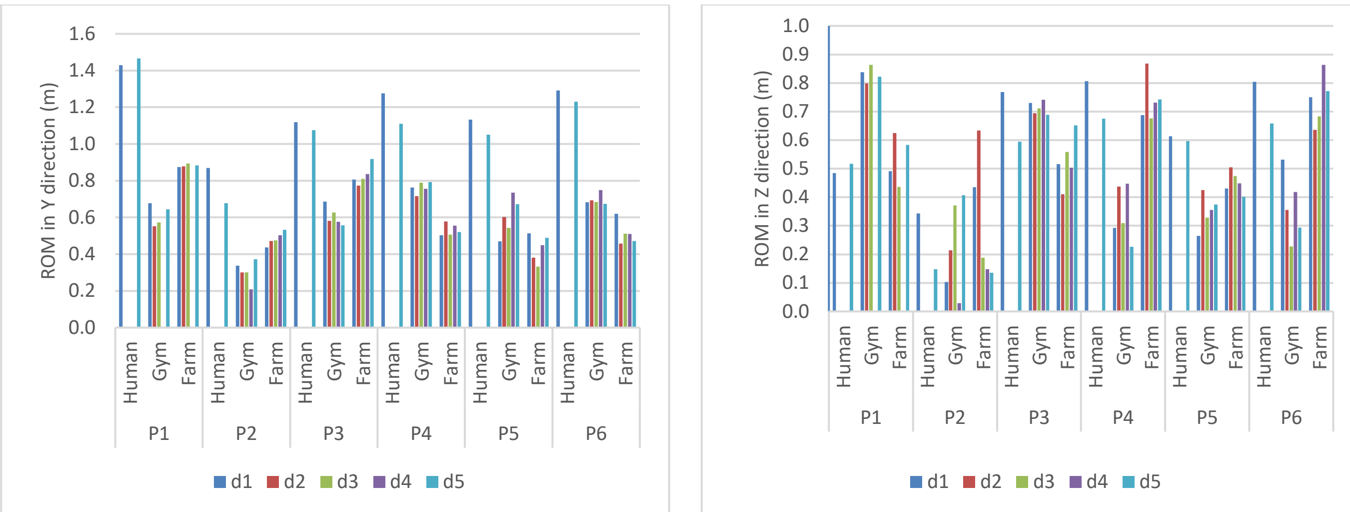


Figure 20. Range of motion of participants in lift overhead activity.

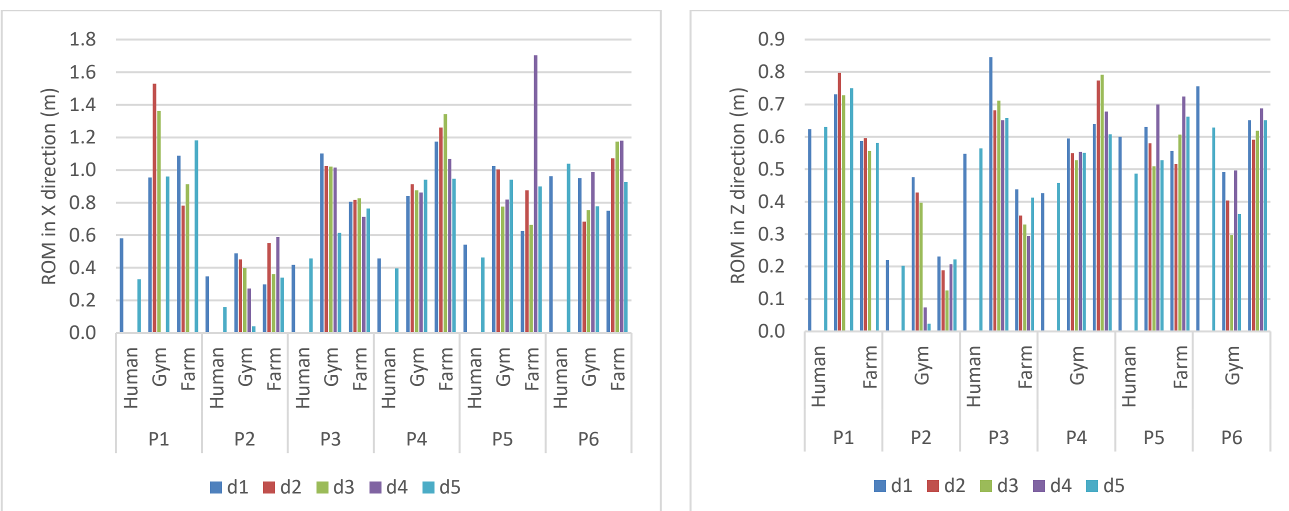


Figure 21. Range of motion of participants in reach forward straight activity.

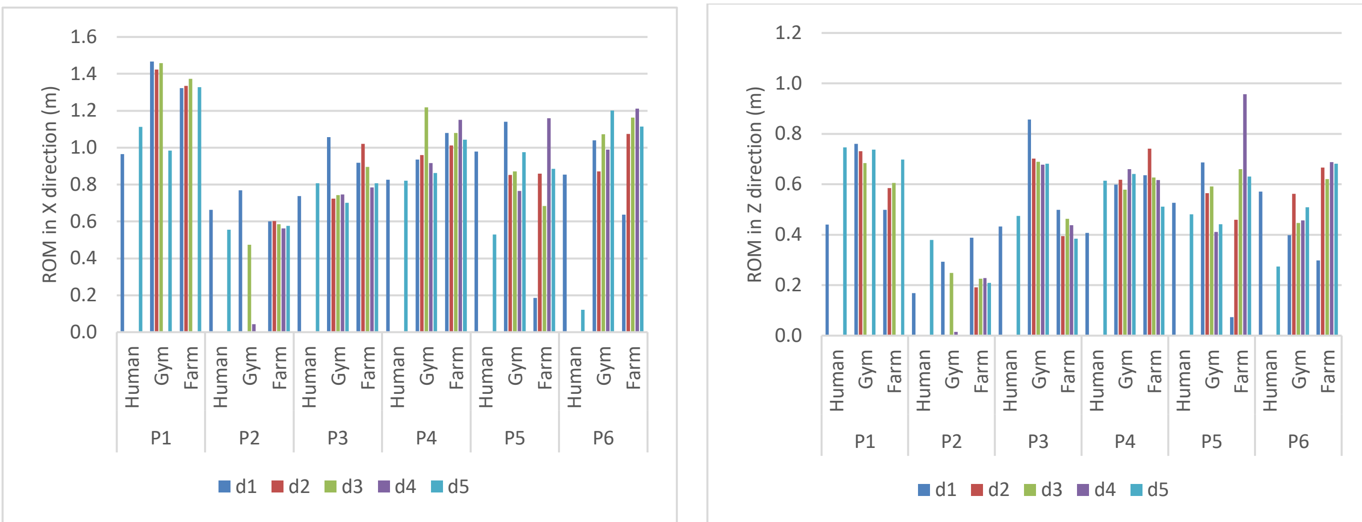


Figure 22. Range of motion of participants in reach forward cross activity.

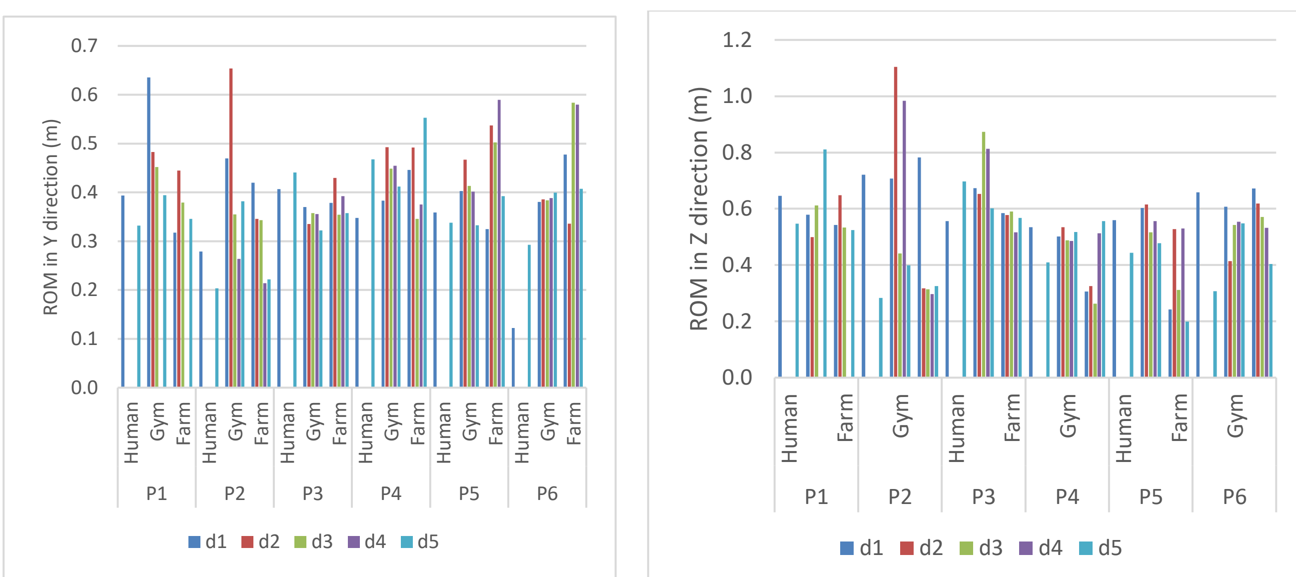


Figure 23. Range of motion of participants in rowing activity.

Simply looking at the plotted data in the above figures, there is no clearly visible trend in the ROM of the participants in different days of a week. The range of motion of participants can be compared between three weeks in order to investigate the impact of environment. The average of range of motion for participants in three different environments are compared in Figure 24 to Figure 29 for different scenarios for the major direction of movement.

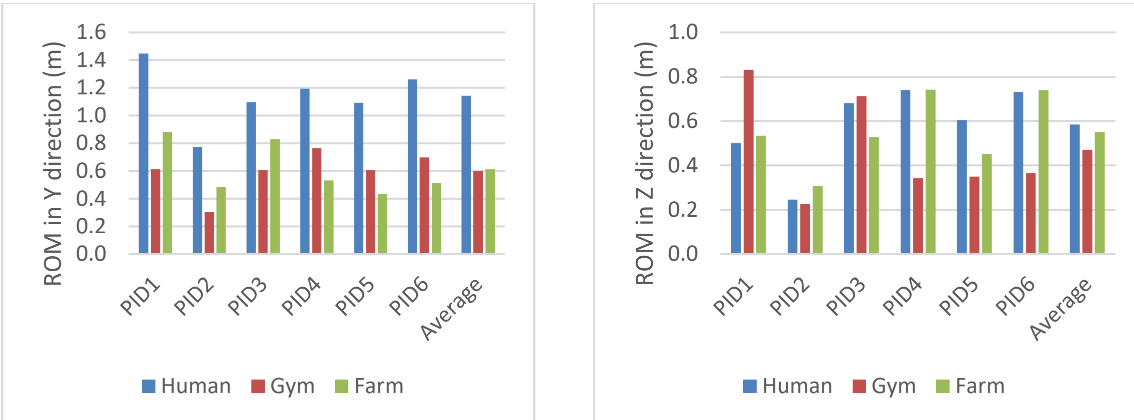


Figure 24. Average ROM of participant in the three environments for the lifting overhead activity.

Based on the average range of motion of participants in reach overhead activity reported in Figure 24, the average of ROM for all users in three conditions of human, gym, and farm is 1.14, 0.59, and 0.61 meter respectively for Y direction (repeated measures ANOVA, $F(2,10)=29.573$, $p=0.00$) and 0.58, 0.47, 0.55 respectively in Z direction (repeated measures ANOVA, $F(2,10)=0.722$, $p=0.509$).

In this activity, the ROM in Y direction shows significant difference where post hoc analysis revealed that the ROM in Y for human-guided were significantly higher than gym ($M=0.546$, $p=0.001$) and gym ($M=0.532$, $p=0.004$) and ROM in Y direction for farm is not significantly higher than gym ($M=0.15$, $p=1$).

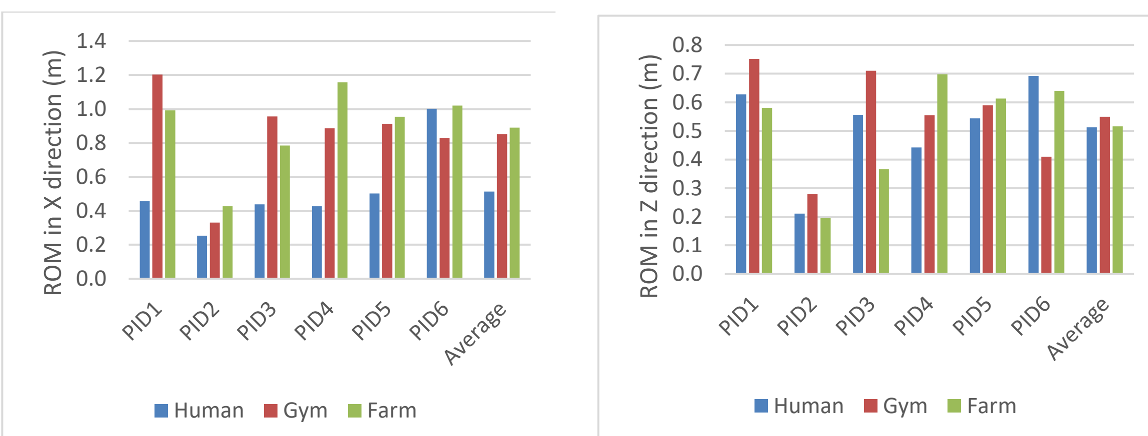


Figure 25. Average ROM of participant in three environments for reach forward straight activity.

Based on the average range of motion of participants in reach straight forward activity reported in Figure 24, the average of ROM for all users in three conditions of human, gym, and farm is 0.51, 0.85, and 0.89 meter respectively for X direction (repeated measures ANOVA, F(2,10)=7.316, p=0.011) and 0.51, 0.55, 0.52 respectively in Z direction (repeated measures ANOVA, F(2,10)=0.168, p=0.848).

In this activity, the ROM in X direction shows significant difference where post hoc analysis revealed that the ROM in X for farm were significantly higher than human-guided (M=0.376, p=0.046) where the difference between farm and gym (M = 0.036, p=1) and human-guided and gym (M=0.340, p=0.16) were not significant.

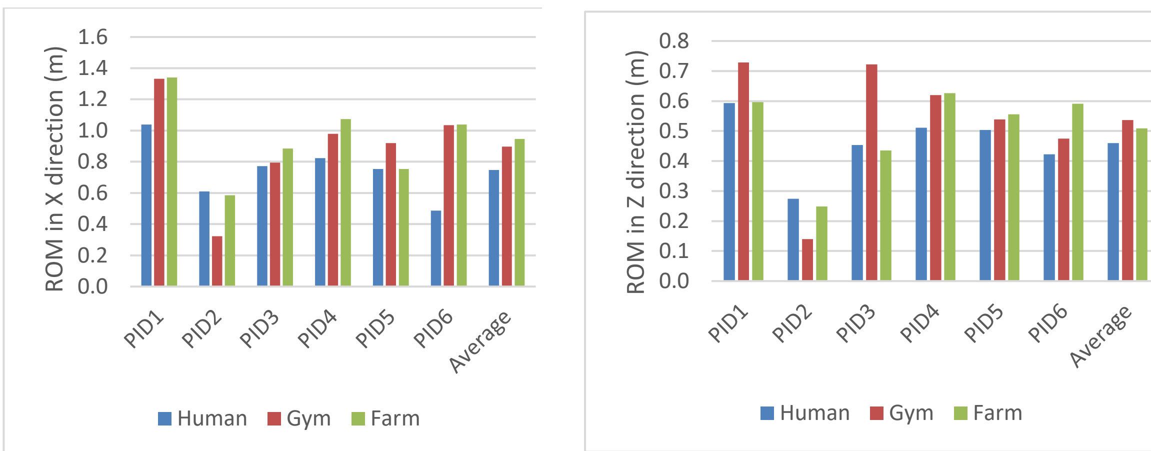


Figure 26. Average ROM of participant in three environments for reach forward cross activity.

Based on the average range of motion of participants in reach straight cross activity reported in Figure 26, the average of ROM for all users in three conditions of human, gym, and farm is 0.78, 0.90, and 0.94 meter respectively for X direction (repeated measures ANOVA, F(2,10)=2.683, p=0.117) and 0.46, 0.54, 0.51 respectively in Z direction (repeated measures ANOVA, F(2,10)=1.153, p=0.354). In this activity, the ROM in X direction shows no significant difference between environments.

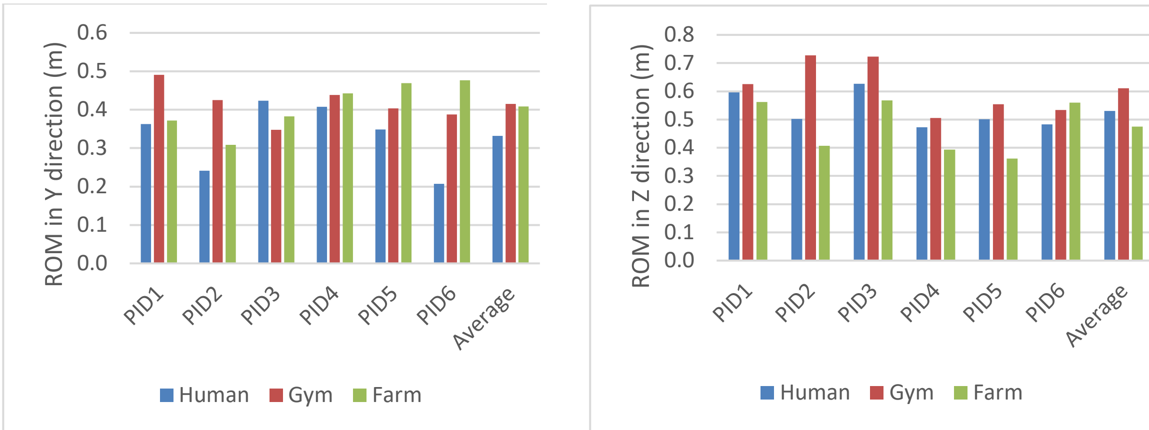


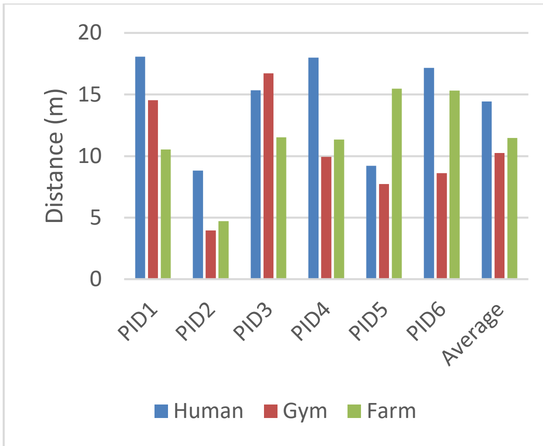
Figure 27. Average ROM of participant in three environments for rowing activity.

Based on the average range of motion of participants in reach straight forward activity reported in Figure 27, The average of ROM for all users in three conditions of human, gym, and farm is 0.33, 0.42, and 0.41 meter respectively for Y direction (repeated measures ANOVA, $F(2,10)=2.575$, $p=0.125$) and 0.53, 0.61, 0.48 respectively in Z direction (repeated measures ANOVA, $F(2,10)=6.794$, $p=0.011$)

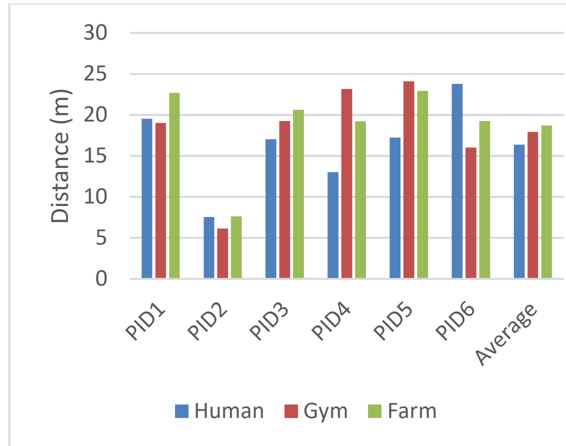
In this activity, the ROM in Z direction shows significant difference where post hoc analysis revealed that the ROM in Z for gym were not significantly higher than human-guided ($M=0.081$, $p=0.132$) or farm ($M=0.136$, $p=0.110$) and there was not significant difference between farm and human guided in ROM for this direction ($M=0.055$, $p=0.381$).

5.6.5 Metrics measurement: Distance traversed

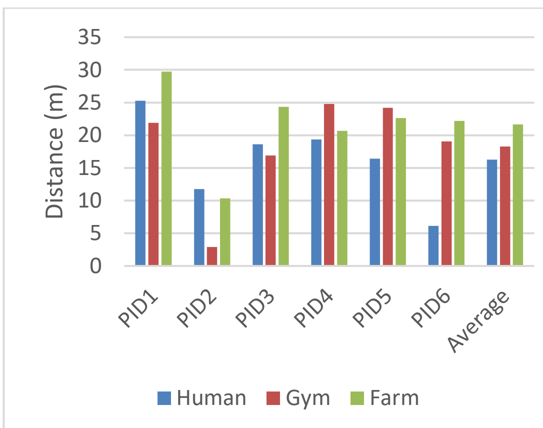
Another parameter that can be measured from the track of hand is the distance travelled by the hands movement during each task. The distance traversed by each participant for an activity is calculated as the total distance traversed by hand during the entire time of that activity. The distance is measured for the five activities that have hand involved. The distance during an activity could represent the level of exercise performed by a participant. Figure 28 shows the average distance traversed by each participant in five days of each week (environment).



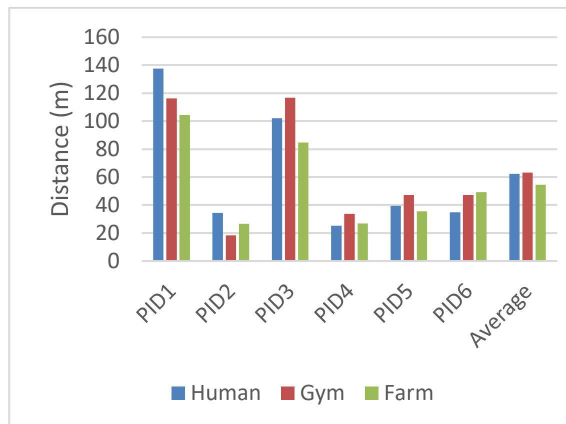
Lift overhead



Reach straight forward



Reach straight cross



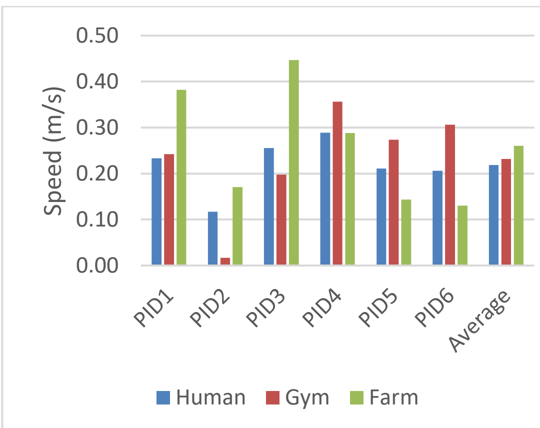
Rowing

Figure 28. Average hand distance traversed by each participant in each activity for three weeks of experiment.

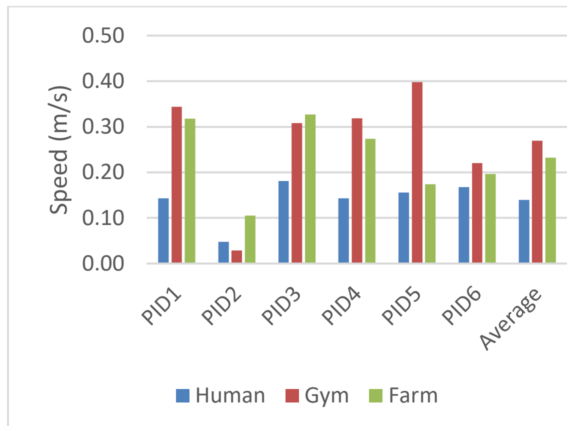
The average distance for all users in three conditions of human, gym, and farm is 14.5, 10.3 and 11.5 meters respectively for lift overhead (repeated measures ANOVA, F(2,10)=2.460, p=0.135), 16.4, 17.9, and 18.7 meters respectively in reach straight forward (repeated measures ANOVA, F(2,10)=0.807, p=0.473), 16.3, 18.3, and 21.6 meters respectively for reach straight cross (repeat measure ANOVA, F(2,10)= 2.090, p=0.174), 62.2, 63.3, and 54.6 meters respectively in rowing (repeated measure ANOVA, F(2,10)= 1.137, p=0.359). There is no significant difference between the distance traversed in different environments by participants.

5.6.6 Metrics measurement: Speed

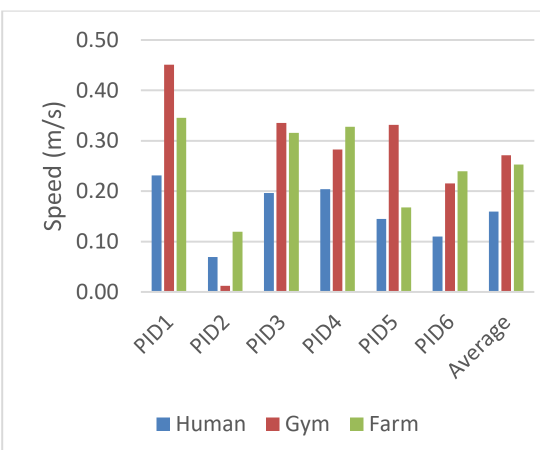
The speed of motion in an activity can be compared in the three environments to shows how fast a participant moved in different environment. Any significant difference in the speed of motion in an environment versus another can be a sign of more engagement in an activity. The lower the motion speed for a participant could be either because of less interest in activity of higher cognitive level requirement which causes time for decision or interaction with the environment. The speed of movements is compared in Figure 29 for all participant and different environments.



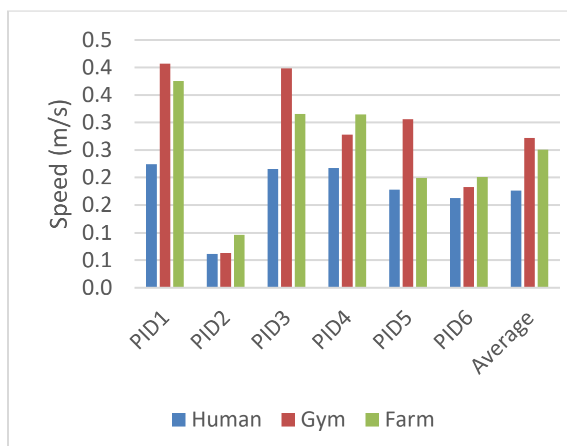
Life overhead



Reach forward straight



Reach forward cross



Rowing

Figure 29. Average speed of motions for each participant in each activity for three weeks of experiment.

The average speed of all users in three conditions of human, gym, and farm is 0.22, 0.23, 0.26 meter/second respectively for lift overhead (repeated measures ANOVA, $F(2,10)=0.332$, $p=0.725$) which shows no significant difference.

The average speed of all users in three conditions of human, gym, and farm is 0.14, 0.27, and 0.23 meter/second respectively in reach forward straight (repeated measures ANOVA, $F(2,10)=6.650$, $p=0.015$) which shows significant difference. Post hoc analysis revealed that for reach forward straight the speed in human-guided were significantly lower than gym ($M=-1.3$, $p=0.068$) and farm ($M=-0.92$, $p=0.057$) and there was insignificant difference between farm and gym for the speed ($M=0.038$, $p=1$).

For reach forward cross activity the average speed of all users in three conditions of human, gym, and farm is 0.16, 0.27, and 0.23 meter/second respectively (repeat measure ANOVA, $F(2,10)= 6.008$, $p=0.19$), which shows insignificant difference.

The speed average for rowing activity is 0.18, 0.27, and 0.25 meter/second respectively (repeated measure ANOVA, $F(2,10)= 7.153$, $p=0.019$) which shows significant difference between environments. Post hoc analysis revealed that for rowing, the speed in gym were significantly higher than human-guided ($M=-1.3$, $p=0.068$) and the speed in farm were also significantly higher than human-guided ($M=-0.92$, $p=0.057$). Based on post hoc analysis, there is no significant difference between speed average in farm and gym (). and there was insignificant difference between farm and gym for the speed ($M=0.038$, $p=1$).

5.7 Summary

In summary, the results obtained from different evaluation metrics show no significant preference of one environment in overall. The results from participants questionnaire showed a higher score of enjoyment for VR games however the difference is not significant. Evaluation of other parameters from participant questionnaire such as interest, engagement, and easiness also show comparable performance in VR and human guided which shows the success of VR. Motion and fitness parameters obtained from device sensors and clinical measurement show that participants motions and fitness in VR has been quantitatively comparable to human-guided. In just a few cases, there are significant observations of difference between environments for motion parameters, however, the higher value has been for the different environments in these cases. In addition to the motion analysis, feedback of kinesiologists and exercise therapist about the exercise program contains valuable points which should be considered for further discussion and improvement.

Chapter 6
Empirical study evaluating the HMD-VR exergame for people living with dementia: Discussion

To investigate the success of the exercise program design, the goal of the project and the research questions should be considered. The main goal of this study was to engage PWD in exercise using HMD-VR games. The main research questions in this study were, can PWD work with HMD-VR and is there any subjective or objective differences in exercise using HMD-VR games compared to human-guided exercise. Some evaluation methods were developed (as explained in section 4.5) to assess the success of the design based on various aspects. As stated in the opening paragraph of Chapter 5, a subjective evaluation of qualitative data was used to gain a deeper understanding of participants' perceptions from their feedback. This chapter discusses the outcomes of this study by focusing on the research questions. The evaluation methods and their output reported in Chapter 5 are used to address the main outcomes and evidence. As no studies were found in the literature review with the goal of exercise motivation for PWD using HMD-VR, I evaluated the outcomes of this study based on targeted objective questions and successful metrics as discussed in chapter 4.

One of the concerns that was pointed out by kinesiologists in the design process (as explained in Chapter 3), and was also one of the main research questions in this study, was the feasibility of using the new technology of HMD-VR for PWD to use in exercise. In the experiments within this study, all the participants completed the exercises using HMD-VR on all days of the study. In addition, based on the reported results of their feeling about their workout (Table 1) they felt that they had an adequate workout by exercising with VR. There were only few problems observed in using the touch controllers and HMD for participants mostly in their first trials. They could interact with objects as designed for each game. One of the parameters that can reflect the feelings of participants using HMD-VR is the level of ease reported in the daily questionnaires as reported in section 5.1. Based on the results reported for ease of exercise in the farm scenario (Figure 11), the participants found exercising with the device easier than exercising with the guidance of a human. The ease of use has also been mentioned in some of the quotes from participants' interviews reported in Section 5.2 All these evidences show that there is no problem using this new technology for PWD for exercise. This reported feeling of ease of use was surprising.

The design of the device could impact the ease of using a game controller. The Oculus rift CV1 touch controller used in this exercise program has an ergonomic design, which could also be a factor that helped to make interactions easy. The usage of other game controllers available on the market could be the subject of future research. The role of design considerations such as using no button of game controllers to make interactions easy should also be considered in future studies for PWD.

Subjective analysis of the participants' feelings was another method applied to assess the success of the study. Feelings of users including interest, enjoyment, ease of use, comfort, and having an adequate workout were recorded using questionnaires as reported in Chapter 5. Enjoyment level as reported in Figure 10 shows a higher average level for VR environments although the difference is not significant. The ease of use, comfort, engagement and comfort level reported in Figure 11 shows the comparable values between human-guided and two VR environments. Based on a statistical analysis of the levels of these four parameters, there is no significant difference between the three environments (human-guided, gym, and farm); but considering the complexity of activities and interactions in VR compared to human-guided exercise, this similarity in the level of these parameters shows that the participatory design process resulted in the selection of the proper activities and interfaces. The success of this design approach can lead to using a similar approach for future research on using VR for PWD.

One of the methods that can make statistical analysis of subjective data more reliable is increasing the number of participants. Recruiting more PWD for an experiment can result in a more reliable statistical analysis of users' feelings; however, it is difficult to manage sessions for more PWD in one place. The diversity of interests and abilities of PWD highlight the need to involve more participants to reach a better analysis of results.

As the aim of the study was the design of an exercise program, the clinical measurements of fitness parameters and recording the motion parameters from the device can also show both engagement of the participants in the exercise program and any possible physical health improvement. As discussed in section 4.5, better or even comparable fitness and motion parameter values can indicate the success of the design in engaging exercise.

Of the fitness parameters, such as head-to-wall, reach upward/downward, and grip strength, reported in Table 2 and Figure 12-14, there was no significant improvement reported in the measured values in different steps of the experiment and it was expected as the intervention was so short. However, keeping the users at a similar level of fitness during the experiment is a factor that can be considered as a success.

From the analysis of motion parameters recorded by the device's sensors in the experiment, as reported in section 5.6, it can be seen that, in general, the VR games worked as well as human-guided methods in engaging PWD to exercise. There was no significant preference that can be observed in all the activities; however, in some activities, one of the environments showed higher values in one of the motion parameters. Here, in speed of motion, VR games showed significantly better results in two activities (reach straight forward and rowing). This can show that the users can easily follow the instructions and were interested in doing activities faster in VR games.

Of the motion parameters evaluated in this experiment, the analysis of distance traversed by participants in different activities shows no significant difference between the three environments. This is a very interesting result as the users had comparable motions in VR while playing the game compared to a real exercise session in which the user is repeating the actions of a person to do the exercise. This is even more interesting if we consider the diverse physical abilities and preferences of PWD because the subject of activities in VR games could be the preference of some participants but not others. This can be one important piece of evidence for the success of the designed game.

Quantitative analysis of ROM as one of the motion parameters can show whether the VR exergame has been successful or not. Based on the results reported on the range of motion in major movement direction in the previous chapter, ROM in the Y direction for the reach overhead activity had a significantly higher value for human guided exercise, and ROM in the x direction of the reach forward straight activity shows a significantly higher level in the VR games. In the reach forward cross activity there is no significant difference in the reported ROM between environments while in rowing, the gym environment had the highest value of ROM in the Z direction. In general, no environment had significantly higher values in all the measurements of ROM for all activities; therefore, there is no straightforward conclusion regarding preference. However, observing the different preferences for environments in different activities can be due to differences in distances in VR and the range of motions guided by a human mentor guided the users. Despite these differences in preference of environments, making all interactions in VR by participants shows that the interactions were designed carefully to have all the objects within a reachable distance for the user. This helped participants to continue the game and complete all the activities.

The feedback of kinesiologists is one of the parameters that can indicate the success of the design in terms of the proper selection of motions and activities for PWD. Based on the report of kinesiologists' feedback (section 5.5) on the level and type of motions selected in this study, there was general agreement as to the suitability of the level of exercise, and most of the kinesiologists (From Figure 15) confirmed that proper movements had been selected for the experiment.

One of the limitations of this study was in the selected seated position for activities. As discussed in Chapter 3, the seated position was chosen for safety. It limits the design, as only upper body motions are possible to be performed when the participant is seated in a chair or wheelchair. As it is reviewed in Chapter 2, many studies selected motions including both upper and lower body, especially walking, and many benefits are reported from these studies, especially in improving balance problems for PWD. Exercise in the standing position and with standing position would be more challenging when participants use HMD and will increase the risk of fall. However, for PWD, engaging in seated movements can still provide challenging exercise. Thus I believe it was a reasonable decision for safety despite the limitations on the types of exercise. Investigating the lower-body motion, as it is mentioned in the kinesiologists' feedback, was one of the suggested extensions to this study.

All in all, there is much evidence for the success of the designed exergame in VR based on subjective and objective analysis, and the feedback from kinesiologists in support of the design. However, there are some aspects that need more investigation by extending the number of participants or adding more activities.

Chapter 7
Conclusions and Future Directions

This chapter summarizes the research and its finding and proposes possible future work.

7.1 Summary

The goal of this research was to create virtual reality games that would motivate PWD to engage in physical exercise. The participatory approach in design was followed in collaboration with experts in Schlegel Villages. This participatory approach provided the means to create an appropriate HMD-VR game as well as supported testing of the game with PWD. Discussions with kinesiologists and therapists in different meetings during the design stages led the research team to select proper actions, tailor the game to people's abilities, and create an environment that was appropriate and engaging.

Various subjective and objective evaluations were used to investigate the success of exercise program design in engaging PWD to exercise. The main subjective evaluation used participant questionnaires, and the objective analysis was performed using clinical measurements and motion parameters extracted from sensor data.

After three weeks of experiments, with three conditions and six participants, the results from the participant feedback showed no significant difference in parameters such as enjoyment, comfort, interest, and ease of use between human-guided, gym, and farm. Despite participants experiencing a new technology and a novel game design, our results are comparable with a one-on-one human-guided exercise program. This finding shows the relative success of the participatory approach in designing intuitive and interesting environments and actions while keeping the interface and interactions as simple as possible. To gain more comprehensive and reliable analysis and conclusions will require an extension of the project to involve more participants so as to provide more accurate and meaningful statistical analysis.

To investigate the impact of this physical exercise program on the fitness levels of participants, clinical measurements were performed at various steps in the experiment. However, no meaningful changes were observed from these measurements. On the other hand, the data obtained with the touch controller sensors showed differences arising from the various activities (gym and farm). However, there is no unique trend in the observations from these differences. In general, the VR exercise was close to human-guided exercise in its motion parameters, but it also provided an interesting environment for daily activity tasks, is customizable for each user and can provide a greater variety of activities than simple human-guided exercise.

This research demonstrates that exergames can be developed for PWD and their efficacy appears to be comparable to human-guided exercise. It forms a promising basis for future works in games for supporting exercise for PWD.

7.2 Future work

Many directions for extension or improvement of this project can be considered as possible future work. One of the main limitations of the experiment was the limited number of participants. On the other hand, the recruitment of participants with dementia is difficult, and running experiments for more participants makes the daily scheduling of sessions challenging. Having more participants would improve the statistical analysis with more reliable conclusions. In addition, more participants would provide better representation of the entire population of PWD, as they have various characteristics and a wide range of physical and mental abilities.

To provide a more interesting exercise experience in VR, the number of environments and activities can also be increased. Increasing the number of activities could involve two possible changes: longer times for each session or a wider selection of exercise options. Both options will introduce new challenges. Increasing the duration of a session may cause fatigue, which may reduce the positive feelings participants have about exercise. A wider selection of exercises tested with a wider range of participants may produce a more reliable analysis of the impact of each game. Having a choice in which activity they do, based on their preference, would make participation more enjoyable and provide more insight as to which activities are preferred by PWD.

One of the important parameters in the design of exercise programs for PWD is considering their wide range of variation in physical abilities and limitations. In addition to applying calibration that modifies distances and provides accessible objects to interact with in the virtual environment, the levels of exercise can also be customized based on the abilities and moods of each participant. Modifying the level of exercise in a VR game can be done by providing different levels for the same game or updating the number of objects or items in the game.

Other modifications could involve extending the calibration to promote a wider range of motion, including activities targeting lower body motions.

Appendix A: After session feedback form

Participant ID: ____________ Date: ____________________

After each day's session feedback

1. What is your mood today?

Very bad mood	Bad mood	Neither good nor bad mood	Good mood	Very good mood

2. How much did you enjoy the session?

Hated it	Disliked it	Neither liked nor disliked	Liked it	Loved it

3. Do you feel you got good exercise from this session?

Yes	No

4. Is there anything else about the session that you would like to share with us today?

Page 1 of 1 October-25-17 After session feedback form

Appendix B: After activity feedback forms for all three weeks

Participant ID: ____________ Date: ____________________

After activity feedback (asked after Friday's session)

Week I: Activity A

1. How much did you enjoy the activity you did this week?

Hated it	Disliked it	Neither liked nor disliked	Liked it	Loved it

2. How comfortable or uncomfortable did you feel doing this activity?

Very uncomfortable	Uncomfortable	Neither comfortable nor uncomfortable	Comfortable	Very comfortable

3. How easy or difficult did you find it to do what was being asked in the activity?

Very difficult	Difficult	medium	Easy	Very easy

4. How engaged did you feel in the activity?

Not engaged at all	Somewhat engaged	Very engaged	Extremely engaged

Page 1 of 2October-25-17 After activity feedback form week 1

Participant ID: _____________ Date: ____________________

5. How interesting did you find the activity?

Not interesting at all	Somewhat interesting	Interesting	Very interesting	Extremely interesting

6. Would you like to do this exercise again in the future?

Yes	No

7. Is there anything else about this week's exercise that you would like to share with us today?

Page 2 of 2October-25-17 **After activity feedback form week 1**

Participant ID: ____________ Date: ____________________

After activity feedback (asked after Friday's session)

Week II: Farm / Gym

1. How much did you enjoy the activity you did this week?

Hated it	Disliked it	Neither liked nor disliked	Liked it	Loved it

2. How comfortable did you feel doing this activity?

Very uncomfortable	Uncomfortable	Neither comfortable nor uncomfortable	Comfortable	Very comfort able

3. How easy did you find it to do what was being asked in the activity?

Very difficult	Difficult	Medium	Easy	Very easy

4. How engaged did you feel in the activity?

Not engaged at all	Somewhat engaged	Very engaged	Extremely engaged

Page 1 of 2October-25-17 After activity feedback form week2

Participant ID: _____________ Date: _____________________

5. How interesting did you find the activity?

Not interesting at all	Somewhat interesting	Interesting	Very interesting	Extremely interesting

6. Would you like to do this exercise again in the future?

Yes	No

7. Last week you exercised with Laura. This week you exercised with a computer game. Which one did you find more interesting?

The exercise with Laura	They were both interesting	The exercise with the computer game

8. Which exercise do you find easier to follow?

The exercise with Laura	They were both easy	The exercise with the computer game

9. Which exercise do you find more engaging?

The exercise with Laura	They were both engaging	The exercise with the computer game

10. Is there anything else about the two kinds of exercises (this week and last week) that you would like to share with us today?

Page 2 of 2October-25-17 After activity feedback form week2

Participant ID: ____________ Date: ____________________

After activity feedback (asked after Friday's session)

Week III: Farm / Gym

1. How much did you enjoy the activity you did this week?

Hated it	Disliked it	Neither liked nor disliked	Liked it	Loved it

2. How comfortable did you feel doing this activity?

Very uncomfortable	Uncomfortable	Neither comfortable nor uncomforta ble	Comfortable	Very comfortable

3. How easy did you find it to do what was being asked in the activity?

Very difficult	Difficult	Medium	Easy	Very easy

4. How engaged did you feel in the activity?

Not engaged at all	Somewhat engaged	Very engaged	Extremely engaged

5. How interesting did you find the activity?

Not	Somewhat	Interesting	Very	Extremely

interesting at all	interesting		interesting	interesting

6. Would you like to do this exercise again in the future?

Yes	No

7. Which computer game exercise environment did you find the most interesting?

The Farm Environment	They were both interesting	The Gym Environment

Why?

8. Which computer game environment did you find easier to follow?

The Farm Environment	They were both easy	The Gym Environment

Why?

9. Which computer game environment did you find more engaging?

The Farm	They were both	The Gym

Environment	engaging	Environment

Why?

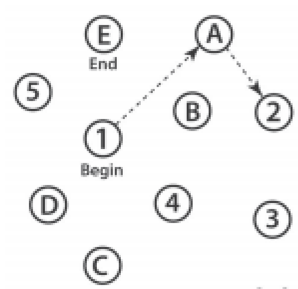
10. Is there anything else about the three kinds of exercise environments (with Laura, on the Farm and in the Gym) that you would like to share with us today?

Appendix C: Montreal Cognitive Assessment (MoCA)

MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

Name:
Education: **Date of birth:**
Sex: **DATE:**

VISUOSPATIAL / EXECUTIVE



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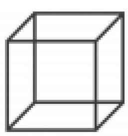

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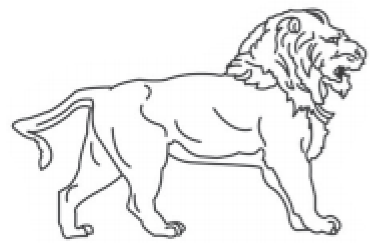

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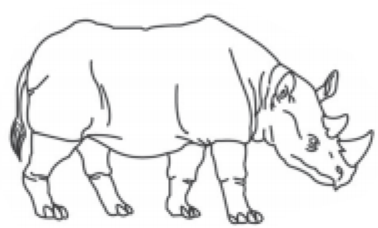

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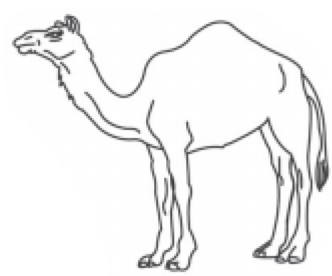

☐

___/3

MEMORY		FACE	VELVET	CHURCH	DAISY	RED	POINTS
Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.	1st trial						
	2nd trial						No points

ATTENTION

Read list of digits (1 digit/sec)

Subject has to repeat them in the forward order ☐ 2 1 8 5 4

Subject has to repeat them in the backward order ☐ 7 4 2

__/2

Read list of letters. The subject must tap with their hand at each letter A. No points if ≥ 2 errors

☐ FBACMNAAJKLBAFAKDEAAAJAMOFAAB

__/1

Serial 7 subtraction starting at 100 ☐ 93 ☐ 86 ☐ 79 ☐ 72 ☐ 65

4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt** 0 correct: **0 pt**

__/3

LANGUAGE

Repeat: I only know that John is the one to help today. ☐

The cat always hid under the couch when dogs were in the room. ☐

__/2

Fluency / Name maximum number of words in one minute that begin with the letter F

☐ ____ (N ≥ 11 words)

__/1

ABSTRACTION

Similarity between e.g. banana – orange = fruit ☐ train – bicycle ☐ watch – ruler

__/2

DELAYED RECALL	Has to recall words **WITH NO CLUE**	FACE ☐	VELVET ☐	CHURCH ☐	DAISY ☐	RED ☐	Points for UNCUED recall only	__/5
Optional	Category cue							
	Multiple choice cue							

ORIENTATION ☐ Date ☐ Month ☐ Year ☐ Day ☐ Place ☐ City __/6

© Z.Nasreddine MD www.mocatet.org Normal ≥ 26 / 30

TOTAL __/30

Add 1 point if ≤ 12 yr edu

Administered by: ______________________

Appendix D: SFFA protocol in clinical measurement

Schlegel-UW Research Institute for Aging

SFFA | TEST ADMINISTRATION GUIDE

Modified: February 4, 2015 (sgbrown)

RIA Research Institute for Aging
Schlegel • UWaterloo • Conestoga

Participant ID: ______________ Date: ______________________

[BEFORE REACHING TASKS: MEASURE HEIGHT AND HEAD-TO-WALL DISTANCE]

HEIGHT: Resident stands with heels together, bum and shoulders against the wall

HEAD-TO-WALL: Resident presses shoulders and sacrum into wall. Be sure there is no chin retraction and bottom of ear and eye are on same plane. Measure distance from occiput to wall

RESIDENT REACHES DOWNWARD

ADMINISTRATOR SCRIPT:
This task looks at your ability to reach down and pick up an object from the floor. You'll see that there is a dowel on the floor in front of you.
[POINT OUT DOWEL]

The dowel can easily be picked up.
[DEMONSTRATE PICKING UP THE DOWEL]

For this task, you are going to begin in a standing position, and will reach down to pick up the dowel. Be sure to pick it up as close to the floor as you can.
[DEMONSTRATE PICKING UP DOWEL CLOSE TO FLOOR]

After you've picked up the dowel, do not move your fingers until I've taken my measurement.

NOTE TO ADMINISTRATOR:
When setting up the equipment for this task, be sure to place the dowel slightly off-centre in order to avoid injury if the resident happens to bend down too far. Also be sure to ask them which side they prefer the dowel to be on.

RESIDENT REACHES UPWARD

ADMINISTRATOR SCRIPT:
This task looks at your ability to reach for objects on a shelf. Standing with the side of your foot against the wall, we would like you to reach as high as you can while maintaining a straight arm [DEMONSTRATE]. I will be standing right beside you in case you lose your balance.

We will start with the right arm. [RIGHT ARM]

Ok, now can you please turn to the other side and perform the reaching task with your left arm [LEFT ARM]

Schlegel Villages Page 1 of 2 University of Waterloo

NOTE TO ADMINISTRATOR:
During the task, ensure that the resident is not rotating his/her reaching arm and is reaching up, hinging from the shoulder. The resident can use any strategy to complete the task **as long as he/she keeps his/her feet flat on the floor.**

GRIP STRENGTH

ADMINISTRATOR SCRIPT:
This task measures your hand grip strength. Research shows that hand grip strength is correlated with overall body strength.

We are going to use this device to measure your grip strength.
[SHOW DYNAMOMETER]

We will take 2 measurements with each hand. You will hold the device at your side, and squeeze as hard as you can.
[DEMONSTRATE PROPER POSITION]

Be sure that you keep breathing out as you are squeezing – lots of people hold their breath while they do this task, but it is best if you keep breathing as normally as possible.

We'll alternate between your right and left hands.

We will start with the right hand. Breathe IN [BREATHE IN WITH THEM], then breathe OUT AND SQUEEZE [BREATHE OUT WITH THEM NOISILY]

[RIGHT HAND TRIAL #1]
Now we will do the left hand. [LEFT HAND TRIAL #1]
Once more with the right hand. [RIGHT HAND TRIAL #2]
The last attempt will be with the left hand. [LEFT HAND TRIAL #2]

Appendix E: Shoulder circumduction protocol

Participant ID: _____________ Date: ______________________

Shoulder Circumduction Test

ADMINISTRATOR SCRIPT:
This task is to assess your shoulder flexibility.

First we measure a distance between 2 prominences on your shoulders using a flexible measuring tape.
[Show the tape and do measurement and indicate two point with that distance in the tape]

You need to grasp the tape at these two points in front of you.
[show how to keep the tape using two holding point in front]

Then move it up over your heads with locked elbows (performing circumduction)
[Do the motion yourself]

Letting the tape slide through your hand until it reaches the widest width and the tape ends up behind you
[show the motion from the side and back]

Now, keep the tape and do not let tape to slide through your hand. I need to measure the distance between new points on tape.
[Take the tape using the fixed points and measure the distance between two them]

NOTE TO ADMINISTRATOR:
Before the task make sure that the user is standing in a place with enough space at back for doing the motion.

Appendix F Abbey pain scale

Abbey Pain Scale

For measurement of pain in people with dementia who cannot verbalise.

How to use scale: While observing the resident, score questions 1 to 6

Name of resident: ………………………………………………………………………….

Name and designation of person completing the scale: …………………………

Date: …………………………………………**Time:** ………………………………………

Latest pain relief given was…………………………………………**at** ………..**hrs.**

Q1.	**Vocalisation** **eg. whimpering, groaning, crying** *Absent 0 Mild 1 Moderate 2 Severe 3*	**Q1**	☐
Q2.	**Facial expression** **eg: looking tense, frowning grimacing, looking frightened** *Absent 0 Mild 1 Moderate 2 Severe 3*	**Q2**	☐
Q3.	**Change in body language** **eg: fidgeting, rocking, guarding part of body, withdrawn** *Absent 0 Mild 1 Moderate 2 Severe 3*	**Q3**	☐
Q4.	**Behavioural Change** **eg: increased confusion, refusing to eat, alteration in usual patterns** *Absent 0 Mild 1 Moderate 2 Severe 3*	**Q4**	☐
Q5.	**Physiological change** **eg: temperature, pulse or blood pressure outside normal limits, perspiring, flushing or pallor** *Absent 0 Mild 1 Moderate 2 Severe 3*	**Q5**	☐
Q6.	**Physical changes** **eg: skin tears, pressure areas, arthritis, contractures, previous injuries.** *Absent 0 Mild 1 Moderate 2 Severe 3*	**Q6**	☐

Add scores for 1 – 6 and record here ⇨ **Total Pain Score** ☐

Now tick the box that matches the Total Pain Score ⇨

0 – 2 No pain	3 – 7 Mild	8 – 13 Moderate	14+ Severe

Finally, tick the box which matches the type of pain ⇨

Chronic	Acute	Acute on Chronic

Dementia Care Australia Pty Ltd
Website: www.dementiacareaustralia.com

Abbey, J; De Bellis, A; Piller, N; Esterman, A; Giles, L; Parker, D and Lowcay, B.
Funded by the JH & JD Gunn Medical Research Foundation 1998 – 2002

Appendix G Participants range of motion in different days

For each activity in each day of the experiment, the range of motion is measured for each targeted motion. The following tables are the numerical report of the ROM values.

Table 4. ROM (m) of Y direction of lifting overhead activity.

	P1			P2			P3			P4			P5			P6		
day	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	1.43	0.68	0.87	0.87	0.34	0.44	1.12	0.69	0.81	1.28	0.76	0.50	1.13	0.47	0.51	1.29	0.68	0.62
d2	-	0.55	0.88	-	0.30	0.47	-	0.58	0.77	-	0.72	0.58	-	0.60	0.38	-	0.69	0.46
d3	-	0.57	0.89	-	0.30	0.47	-	0.63	0.81	-	0.79	0.51	-	0.54	0.33	-	0.68	0.51
d4	-	-	-	-	0.21	0.50	-	0.58	0.84	-	0.76	0.55	-	0.74	0.45	-	0.75	0.51
d5	1.47	0.64	0.88	0.68	0.37	0.53	1.08	0.56	0.92	1.11	0.79	0.52	1.05	0.67	0.49	1.23	0.67	0.47

Table 5. ROM (m) of Z direction of lifting overhead activity.

	P1			P2			P3			P4			P5			P6		
day	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.48	0.84	0.49	0.34	0.10	0.44	0.77	0.73	0.52	0.81	0.29	0.69	0.61	0.26	0.43	0.80	0.53	0.75
d2	-	0.80	0.62	-	0.21	0.63	-	0.69	0.41	-	0.44	0.87	-	0.43	0.50	-	0.36	0.64
d3	-	0.86	0.44	-	0.37	0.19	-	0.71	0.56	-	0.31	0.68	-	0.33	0.47	-	0.23	0.68
d4	-	-	-	-	0.03	0.15	-	0.74	0.50	-	0.45	0.73	-	0.36	0.45	-	0.42	0.86
d5	0.52	0.82	0.58	0.15	0.41	0.14	0.59	0.69	0.65	0.68	0.23	0.74	0.60	0.37	0.40	0.66	0.29	0.77

Table 6. ROM (m) of X direction of reach forward straight activity.

day	P1			P2			P3			P4			P5			P6		
	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.58	0.96	1.09	0.35	0.49	0.30	0.42	1.10	0.80	0.46	0.84	1.17	0.54	1.03	0.63	0.96	0.95	0.75
d2	-	1.53	0.78	-	0.45	0.55	-	1.02	0.82	-	0.91	1.26	-	1.00	0.88	-	0.68	1.07
d3	-	1.36	0.91	-	0.40	0.36	-	1.02	0.83	-	0.87	1.34	-	0.78	0.66	-	0.75	1.17
d4	-	-	-	-	0.27	0.59	-	1.01	0.71	-	0.86	1.07	-	0.82	1.70	-	0.99	1.18
d5	0.33	0.96	1.18	0.16	0.04	0.34	0.46	0.61	0.76	0.40	0.94	0.95	0.46	0.94	0.90	1.04	0.78	0.93

Table 7. ROM (m) of Z direction of reach forward straight activity.

day	P1			P2			P3			P4			P5			P6		
	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.62	0.73	0.59	0.22	0.48	0.23	0.55	0.85	0.44	0.43	0.59	0.64	0.60	0.63	0.56	0.76	0.49	0.65
d2	-	0.80	0.60	-	0.43	0.19	-	0.68	0.36	-	0.55	0.77	-	0.58	0.52	-	0.40	0.59
d3	-	0.73	0.56	-	0.40	0.13	-	0.71	0.33	-	0.53	0.79	-	0.51	0.61	-	0.30	0.62
d4	-	-	-	-	0.07	0.21	-	0.65	0.29	-	0.55	0.68	-	0.70	0.72	-	0.50	0.69
d5	0.63	0.75	0.58	0.20	0.02	0.22	0.56	0.66	0.41	0.46	0.55	0.61	0.49	0.53	0.66	0.63	0.36	0.65

Table 8. ROM (m) of X direction of reaching forward cross activity.

day	P1			P2			P3			P4			P5			P6		
	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.97	1.47	1.32	0.66	0.77	0.60	0.74	1.06	0.92	0.83	0.93	1.08	0.98	1.14	0.19	0.85	1.04	0.64
d2	-	1.42	1.33	-	0.00	0.60	-	0.72	1.02	-	0.96	1.01	-	0.85	0.86	-	0.87	1.07
d3	-	1.46	1.37	-	0.47	0.59	-	0.74	0.90	-	1.22	1.08	-	0.87	0.68	-	1.07	1.16
d4	-	-	-	-	0.04	0.56	-	0.75	0.79	-	0.92	1.15	-	0.77	1.16	-	0.99	1.21
d5	1.11	0.98	1.33	0.56	-	0.58	0.81	0.70	0.81	0.82	0.86	1.04	0.53	0.98	0.88	0.12	1.20	1.11

Table 9. ROM (m) of Z direction of reaching forward cross activity.

day	P1			P2			P3			P4			P5			P6		
	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.44	0.76	0.50	0.17	0.29	0.39	0.43	0.86	0.50	0.41	0.60	0.64	0.53	0.69	0.07	0.57	0.40	0.30
d2	-	0.73	0.59	-	0.00	0.19	-	0.70	0.39	-	0.62	0.74	-	0.57	0.46	-	0.56	0.67
d3	-	0.68	0.61	-	0.25	0.23	-	0.69	0.46	-	0.58	0.63	-	0.59	0.66	-	0.45	0.62
d4	-	-	-	-	0.01	0.23	-	0.68	0.44	-	0.66	0.62	-	0.41	0.96	-	0.46	0.69
d5	0.75	0.74	0.70	0.38	-	0.21	0.47	0.68	0.38	0.61	0.64	0.51	0.48	0.44	0.63	0.27	0.51	0.68

Table 10. ROM (m) of Y direction of the rowing activity.

day	P1			P2			P3			P4			P5			P6		
	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.39	0.64	0.32	0.28	0.47	0.42	0.41	0.37	0.38	0.35	0.38	0.45	0.36	0.40	0.32	0.12	0.38	0.48
d2	-	0.48	0.44	-	0.65	0.35	-	0.34	0.43	-	0.49	0.49	-	0.47	0.54	-	0.39	0.34
d3	-	0.45	0.38	-	0.35	0.34	-	0.36	0.35	-	0.45	0.35	-	0.41	0.50	-	0.38	0.58
d4	-	-	-	-	0.26	0.21	-	0.36	0.39	-	0.45	0.38	-	0.40	0.59	-	0.39	0.58
d5	0.33	0.39	0.35	0.20	0.38	0.22	0.44	0.32	0.36	0.47	0.41	0.55	0.34	0.33	0.39	0.29	0.40	0.41

Table 11. ROM (m) of Z direction of rowing activity.

day	P1			P2			P3			P4			P5			P6		
	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm	Human	Gym	Farm
d1	0.65	0.58	0.54	0.72	0.71	0.78	0.56	0.67	0.58	0.53	0.50	0.31	0.56	0.60	0.24	0.66	0.61	0.67
d2	-	0.50	0.65	-	1.10	0.32	-	0.65	0.58	-	0.53	0.33	-	0.62	0.53	-	0.41	0.62
d3	-	0.61	0.53	-	0.44	0.31	-	0.87	0.59	-	0.49	0.26	-	0.52	0.31	-	0.54	0.57
d4	-	-	-	-	0.98	0.30	-	0.81	0.52	-	0.49	0.51	-	0.56	0.53	-	0.55	0.53
d5	0.55	0.81	0.52	0.28	0.40	0.33	0.70	0.60	0.57	0.41	0.52	0.56	0.44	0.48	0.20	0.31	0.55	0.40

Appendix H Kinesiologists feedback form

ID# K-_______ Date: _______________

VR exergame feedback

1. Do you think the level of effort is appropriate for most of your clients?

No	Not sure	Yes

If not, why not?

2. Are the movements the game elicits movements that you would use with a client?

Not at all	A little	Somewhat	Mostly	Absolutely

3. Are there any motions or movement you would recommend adding?

4. Considering that we can track people's hand and head positions during each activity, are there metrics you think would be valuable / informative?

5. Please mention one or two aspects you feel using VR for exergames does well. Why?

6. Please mention one or two aspects you feel could be improved. How?

7. Any other comments or thoughts you would like to share with us?

Appendix I Information letter and consent form used in hiring participants

Procedure:

The study will take three weeks. In each week, you will focus on one kind of exercise activity. In each week, from Monday to Friday, you will do a task for less than half an hour on each day and after each task your height and head-to-wall distance, grip strength will be measured.Before starting the first task, You will be asked to complete a measure of cognition and try both VR tasks and get a feel of them. You will also have time to practice all the tasks under the guidance of the research team.

Task1:In this task, an expert clinician will guide you in doing exercises. There will be a video camera that records the sessions for researchers to analyze it after. After that, a few short questions will be asked about your experience and recorded. On 5th day of each task an additional survey will fill out. You may decline to answer any question(s) you prefer not to answer by leaving them blank. The list of exercises you will be asked to do is shown in the following table.

Body Part	Action
Neck-Shoulder	Looking up // Looking down
	Looking left // Looking right
	Shrug shoulders up // relax
	Bring R ear to shoulder // L ear to shoulder
Shoulder-Back	Arm circles forward // backwards; increasing/decreasing sizes
	Self-hugging
	Straight arm raise anterior palm down // palm up; 90-180*
	Straight arm raise laterally palm down // palm up; 90-180*
	Straight arm raise posterior palm up
	Vertical punching upwards L // R
	Pat on the back L // R
	Forward reach w both hands // row backwards to chest
	Bent elbows to ribcage w hands together // rotate outwards
	arms extended palms up rotated laterally // rotated medially
	Clockface
	stirring the pot
Elbow-Wrist-Hands	Bent elbows to ribcage w palms up raised to shoulders // lowered
	rolling wrist clockwise // counterclockwise

Task2: In this task, you will do an exercise using the virtual reality system.The activity and virtual environment will be related to gardening. In the garden task, you will use the hand controllers to interact with virtual objects such as shovels, flowers, and butterflies in the virtual world. Videos of you doing the tasks will be recorded. The same questions will be asked and

recorded. On 5th day of each task an additional survey will fill out. You may decline to answer any question(s) you prefer not to answer by leaving them blank.

Task3: In this task, you will also use the virtual reality system. However, the activity and virtual environment will be related to gym work. In the gym task, you will use the hand controllers to interact with virtual objects such as dumbbell and barbell in the virtual world .Videos of you doing the tasks will be recorded. The same questions will be asked and recorded .On 5th day of each task an additional survey will fill out. You may decline to answer any question(s) you prefer not to answer by leaving them blank.

Inclusion and exclusion criteria:

This study will involve up to 15 participants. In order to participate in this study, you must be 60 years and older with the ability to communicate verbally in English and at least four years of education. .If you have motion sickness or you have hearing impairment that may interfere with your ability to understand verbal reminders, or if there are any pre-existing condition that would preclude the exercise activity that advised by neighborhood coordinator and/or Laura Domenicucci. Moreover, If you have a history of epilepsy and/or seizures or pace makers, you will not be eligible for the study.

It is your choice to make if you want to participate in this study. If you choose to join the study, you may still withdraw your participation later at any time without penalty.

Confidentiality and Data Security:

All information you provide is considered completely confidential. Your name will not appear in any publication resulting from this study. Data collected during this study will be retained 10 years in locked cabinets and/or on password protected desktop computers in secure locations in the Department of Systems Design Engineering at the University of Waterloo, also the collected data will not be shared with the staff at Schlegel Villages and that not being included in the study will not impact your care or treatment in any way. Electronic data will not include personal identifying information such as names. However, with your permission, anonymous quotations and video/pictures may be used. Videos and/or photographs are being taken for research and educational purposes, which may be used in medical or scientific books, magazines, journals, classrooms, and conferences. These videos or photographs may contain identifiable features and will be used by the research team to review participants' interactions with the therapist and with the VR system. Faces will be blurred for any video and/or pictures that are used outside of the research team (e.g., for papers or conferences). Because of the use of video recording, your confidentiality cannot be guaranteed.

Risks and Benefits:

We do not anticipate any higher than minimal risk. You will be seated at all times to prevent a fall from occurring during the sessions. Disinfectant wipes will be used to carefully clean the headset and handheld controllers in between participants.

You may feel nauseous or motion sickness during the session using VR. If that happens, taking off the head-mounted display and have a short break may help. If you feel uncomfortable, you may ask the researcher to stop the session or withdraw your participation at any time.

Some people (about 1 in 4000) may have severe dizziness, seizures, epileptic seizures or blackouts triggered by light flashes or patterns, and this may occur while they are watching TV, playing video games or experiencing virtual reality, even if they have never had a seizure or blackout before or have no history of seizures or epilepsy. We will carefully monitor you at all times and support if needed. Symptoms of VR exposure can persist and become more apparent hours after use. Symptoms can include loss of awareness, double vision, impaired balance, discomfort or pain in the head or eyes, and excessive drowsiness. If you experience any of symptoms prior to leaving the testing area, please notify the researcher and remain in the room until the symptoms subside. If you experience any of symptoms after leaving the testing area, please contact the Wentworth Heights Retirement Lead Nurse, either by activating your call bell or dialing extension 8079. Please also notify your Administrator that you experienced a late onset of the symptoms at your next earliest convenience. Involving with virtual environment may be enjoyable for you. There are no other direct benefits to you from participation. The study results may help researchers better understand the effects of new technology using Virtual Reality on older adults with MCI.

During the exercise, if you experience motion sickness more than once, then the researchers may withdraw you from the study. You will be carefully monitored by a trained researcher during the study session.

Research Ethics Clearance:

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 22300). If you have questions for the Committee contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions contact Dr. Shi Cao at shi.cao@uwaterloo.ca. **Questions and Contacts:**

If you have any questions about the study or would like to receive a copy of the results of this study, please contact Professor Shi Cao at shi.cao@uwaterloo.caor Professor Jennifer Boger at jboger@uwaterloo.ca.Thank you for your considering participating in this project.

P: Participant, I: Interviewer

I: My name is Laura Domenicucci and I am a professional exercise therapist at Schlegel Villages. I am currently collaborating with a research team from the University of Waterloo. We are working on a project which is part of Mahzar Eisapour's Master's thesis in uwaterloo under the supervision of Dr. Jenifer Boger and Dr. Shi Cao from system design and engineering department on using virtual reality for fostering activity with people with mild cognitive impairment. I am looking to recruit participants for this study. Would you be interested in learning more?

P: No -> I: Thank you for your time.

P: Yes ->Thank you (proceed with script).

I: Participants in this study will be asked to perform a physical exercise program that was developed by exercise therapists. Some of the exercises will be guided by a therapist and some will use a head mounted display, which presents virtual environment; it is much like watching TV or a video game but with the screen much closer to your eyes. There will be three tasksin total and each task will be performed once per day for five weekdays and the total tasks would be finished in three weeks. Each session in a day will last around half an hour. In order to participate in this study, you must be 60 years and older with the ability to communicate verbally in English and at least four years of education. .If you have motion sickness or you have hearing impairment that may interfere with your ability to understand verbal reminders, or if there are any pre-existing condition that would preclude the exercise activity that advised by neighborhood coordinator and/or Laura Domenicucci. Moreover, if you have a history of epilepsy and/or seizures or pacemakers, you will not be eligible for the study.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. The final decision about participation is yours and, should you choose to participate, you may withdraw from the study at any time.

I: Do you have any questions you would like to ask at this time? (answer any questions)

I: Are you interested in learning more and possibly participating in this study?

P: No

I: Thank you very much for your time.

OR

P: Yes (or I need more info)

I: This is the information letter, which has all of these details along with contact names and numbers on it to help assist you in making a decision about your participation in this study. Please give yourself time to read the form. Feel free to contact us to ask questions at any time. Then if you like to participate in this study please complete and sign this consent form.

Thank you very much for your time.

UNIVERSITY OF WATERLOO

<u>CONSENTFORM FOR PARTICIPANTS</u>

Title of Project: **Virtual Reality for People with Mild Cognitive Impairment**

Research team members:

Name	Department	Phone:	e-mail:
Shi Cao	Systems Design Engineering	519-888-4567 x36377	shi.cao@uwaterloo.ca
Jennifer Boger	Systems Design Engineering	519-888-4567x38328	jboger@uwaterloo.ca
Mahzar Eisapour	Systems Design Engineering		eisapour@uwaterloo.ca

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by the research team as part of Mahzar Eisapour's Masters thesis led by Professors ***Shi Cao and Jennifer Boger*** from ***Systems Design Engineering*** **at the University of Waterloo**. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that videos and/or photographs are being taken for research and educational purposes, which may be used in medical or scientific books, magazines, journals, classrooms, and conferences. These videos or photographs may contain identifiable features and will be used by the research team to review participants' interactions with the therapist and with the VR system. Faces will be blurred for any video and/or pictures that are used outside of the research team (e.g., for papers or conferences).

I am aware that I may withdraw my consent for any of the above statements or withdraw my study participation at any time without penalty by advising the researcher. I may also request that any data collected up to this point be destroyed; if I withdraw consent after the study is complete, I realise my data may already be used and cannot be withdrawn.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 22300). If you have questions for the Committee contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

Page **1** of **September-07-17Consent form**

	Please Circle One	Please Initial Your Choice
With full knowledge of all foregoing, I agree, of my own free will to participate in this study.	YES/NO	________
I agree to the use of anonymous quotations in presentations or reports that come out of this study.	YES/NO	________
I agree to the use of images (photographs or videos) to be shown publicly for publications and educational reasons such as teaching and conference presentation; my face will be blurred for publically shared videos and pictures.	YES/NO	________

Participant Name: ____
(Please print)

Participant Signature: ____

Witness Name: ____
(Please print)

Witness Signature: ____

Date: ____

Data use in future research

Additionally, I consent for data collected in this study to be used in future research. My consent / non-consent to the future use of data does not impact my participation in this study.

_______ I consent for my data to be used in future studies.
_______ I **DO NOT** consent for my data to be used in future studies.

Participant Name: ____
(Please print)

Participant Signature: ____

Witness Name: ____
(Please print)

Witness Signature: ____

Date: ____

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