The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild Dementia or Parkinson's Disease: A Pilot Study

by

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i. Thesis Examination Information

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Thesis title: The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild Dementia or Parkinson's Disease: A Pilot Study

An oral defense of this thesis took place on June 09, 2023 in front of the following examining committee:

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Chair of Examining Committee	Dr. Ginny Brunton
Research Supervisor	Dr. Winnie Sun, Ontario Tech University
Examining Committee Member	Dr. Shilpa Dogra, Ontario Tech University
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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ii. Abstract

Background: For frail older persons with Parkinson's disease (PD) and mild dementia, Tai Chi (TC) is a popular form of exercise. However, due to accessibility issues and negative outcomes, not all movements are suitable for them. Virtual reality (VR) based seated TC (STC) exergames can alleviate these problems because of its simplicity, safety considerations, indoor application, need for less supervision, and real-time feedback capability. This pilot feasibility study aimed to evaluate the acceptability, safety, and usability of using STC exergame by frail older adults with mild dementia or PD.

Methods: A mixed-methods pilot program was conducted among 7 participants with mild dementia or PD who performed the STC exergame using the Xbox 360 Kinect and "your shape fitness evolved Zen" software for 30 minutes.

Results: All the participants completed both sessions with an average performance increase of 35.23% in the second session (SE:5.9, $P<0.05$), indicating that it is feasible to utilize STC exergame by frail older adults with mild dementia or PD. Overall, participants in this study considered STC exergame usable as they found it to be enjoyable (100%), user-friendly (75%) and they were motivated for future use (43%), as well as appreciated its potential for promoting balance and strength (85.70%). . Five major themes were identified from the pilot usability test including (1) willingness to learn new experiences; (2) user-friendly approach to engage in physical movement, relaxation, and mind concentration; (3) motivated to continue with future practice; (4)

overcoming physical and technical challenges; and (5) preferences regarding format to participate in exergame.

Conclusion: The study's findings provide significant insights that will help future applications of the TC exergame for individuals who are older adults with neurological disorders and cognitive impairment.

iii. Author's Declaration

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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The research work in this thesis that was performed in compliance with the regulations of Ontario Shores Centre for Mental Health Sciences, Research Ethics Board under REB Certificate number 21-016-B.

_____ Farzana Rahman

iv. Statement Of Contributions

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

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Table of Content

i. Thesis Examination Information ... *ii*

ii. Abstract ... *iii*

iii. Author's Declaration ... *v*

iv. Statement Of Contributions ... *vi*

v. Acknowledgements ... *vii*

Chapter 1: Introduction ... *1*

Chapter 2: Literature Review ... *13*

Literature review method: ... **13**

Literature review themes: ... **14**

Chapter 3: Methodology ... *33*

Study design ... **33**

Research framework: ... **34**

Sampling: ... **36**

Participants: ... 36

Recruitment: ... 38

Interventions: ... 39

Study Outcomes: ... 43

Data Collection: ... 43

Data Analysis: ... 44

Ethical Considerations (Risks and Benefits): ... 48

Ethical Considerations (Privacy and Confidentiality): ... 50

Chapter 4: Results ... *51*

Demographic information of study sample: ... **51**

Survey results from post-intervention: ... **53**

Task assessment result: ... **57**

Effect sizes for changes from session 1 to 2: ... **63**

Qualitative thematic findings: ... **63**

Willingness to Learn New Experiences ... 64

User-Friendly Approach to Engage in Physical Movement, Relaxation, and Mind Concentration ... 65

Motivated to Continue with Future Practice ... 66

Overcoming Physical and Technical Challenges: ... 68

Preferences Regarding Format to Participate in Exergame: ... 68

Chapter 5: Discussion ... *71*

Chapter 6: Implications and Conclusion ... *82*

References *86*
Appendix *102*

Chapter 1: Introduction

Globally, the largest and fastest-growing demographic is older adults, that is, adults aged 65 years and older (Shenoy & Harugeri, 2015). According to data from Statistics Canada, 14.1% of Canadians were 65 or older in 2010; this increased to 19.0% in 2022. Statistics Canada predicts that older adults will constitute 22.5% of the Canadian population by 2030 (Statistics Canada, 2019). Aging is an inescapable condition that is related with a decline in general health, including physical and cognitive abilities as well as social connections. In particular, declines in balance and cognitive function, which lead to falls, are considered two of the most significant challenges affecting the health and independence of older adults (Ambrose, Paul & Hausdroff, 2013; Monk & Price, 2011). Furthermore, neurodegenerative conditions such as Parkinson's disease (PD) and dementia amplify the probability of falling (Wright et al., 2011). Dementia, the most prevalent type of cognitive impairment, affects around 10% of people over the age of 65, and its incidence rises to 30% in people over the age of ninety (Jellinger & Attems, 2010). As of 2021, there were an estimated 100,000 Canadians living with PD, while there are already 747,000 or more people with dementia in Canada, and 25,000 new instances are discovered each year (Health Agency of Canada, 2021; Wong et al., 2016).

This chapter provides an overview about the effects of PD and dementia, as well as exercise as a potential non-pharmacological intervention to improve balance among person with PD and dementia. The advantages of exercise to improve balance and coordination especially mind-body exercise like Tai Chi (TC) and seated Tai Chi (STC)

are then discussed. Furthermore, the potential of a virtual reality-based Tai Chi (VRTC) exergaming, related technologies, use cases, and benefits along with its shortcomings are thoroughly examined. The chapter ends with a discussion of the thesis study's goal and significance.

Dementia and Parkinson's Disease (PD) and their impacts:

Dementia is a neurodegenerative disorder, characterized by symptoms, including loss of memory, judgment, reasoning, and changes in mood, behavior, and communication ability (Dudgeon, 2010). However, Alzheimer's disease is the most common form of dementia and contributes to most of the cases (Alzheimer's Society Canada, 2018). A person with dementia (PWD) can be characterized by difficulties in speaking, loss of sleep, loss of appetite, swallowing issues, or handling complex activities as a result of which they encounter challenges during social engagement (Tarawneh & Holtzman, 2012). In addition to disturbances in cognition and behavior, this condition leads to a deterioration in the performance of activities of daily living (Feldman et al., 2005; Gaugler et al., 2007; Thomson et al., 2010).

Studies found that in the early stage of Alzheimer's disease, people have deteriorated walking and impaired postural balance (Pettersson, Olsson, & Wahlund, 2005), which increases their risk of falls by three-fold (Harlein, Dassen, Halfens, & Heinze, 2009). Eventually, PWD requires institutionalization due to their inability to carry out daily activities. In Canada, providing adequate therapeutic support for those with dementia

has become complicated and expensive (Chang, Patel & Schulz, 2015), which most patients will experience sooner or later throughout the disease. As dementia is increasing, the economic burden of dementia is expected to increase from $15 billion in 2008 to $153 billion by 2038 due to the increasing prevalence of the disease in Canada (Aminzadeh et al., 2012).

On the other hand, Canada's second most common neurodegenerative disorder, Parkinson's Disease, can be characterized by significant conditions such as bradykinesia (slowness of movement), rigidity (stiffness), resting tremor, and postural instability (Jankovic, 2008), as well as symptom improvement with the administration of levodopa (Lyons & Pahwa, 2011). Postural instability during daily tasks may cause substantial balance impairment, decreased mobility, and an increased risk of falling. The global population of people with PD is anticipated to increase from 6 million to 12 million by 2040 (Dorsey, Sherer, Okun, & Bloem, 2018).

Furthermore, recently, there has been a rise in dementia associated with PD (Parkinson's Disease, 2020). Health administrative data from Ontario showed that as of 2013, nearly 30% of Ontarians with PD also had a co-existing diagnosis of dementia (Parkinson's Disease, 2020). There is a well-established correlation between PD and dementia with balance impairment. Individuals with PD and dementia showed considerably worse balance than those with PD without dementia (Liu et al.,2019; Mancini et al., 2017).

Another aggravating factor is the incidence of frailty in older adults with cognitive disorders and balance impairment, which worsens as the disease advances (Heyn, Abreu, & Ottenbacher, 2004). The prevalence of frailty among older adults can further aggravate the consequences of PD-related postural instability and may even increase the risk of developing dementia from any cause in older persons (Kojima et al., 2016).

Studies have shown that the drugs available for treatment only provide relief of the symptoms and do not stop the progression of the disease (Tarazi et al., 2014). Therefore, searching for non-pharmacological treatments to slow down the rates of motor and non-motor symptom progression in patient with less side effect (Crotty & Schwarzschild , 2020) is valid and necessary to bring effective treatment, such as- exercise and physiotherapy to improve balance among individuals with dementia and PD (Sumec, Filip, Sheardova, & Bares, 2015).

Potential of exercise on balance and cognition:

Exercise is a deliberate, intentional, repeated, and planned form of physical activity (Carek, Laibstain, & Carek, 2011) that offers both physical and mental benefits (Freeman & Lawlis, 2001; Ko et al., 2006; Haskell et al., 2007; van den Berg-Emons et al., 2011; Nguyen & Kruse, 2012). Exercise programs can potentially improve balance among older adults, as well as depression and cognitive performance (Burto et al., 2015; Chen et al., 2009; Angevaren et al., 2008; Erickson et al., 2011; Tseng et al., 2011). Additionally, exercise in middle age may help maintain cognitive function and reduce or delay the risk

of dementia in old age (Hamer & Chida, 2009; Chang et al., 2010). Regular physical activity can improve a variety of physical indices, including strength, step length, balance, mobility, and walking endurance (Lam et al., 2018). Implementing regular physical exercise programs is a viable alternative to demonstrate benefits on motor and non-motor symptoms of PD. However, they require safety monitoring and are equipment-dependent (Dibble et al., 2006, Hirsch et al., 2003, Scandalis et al., 2001) which often make them unsuitable for high intensity exercises. On the other hand, low-intensity exercises (such as Tai Chi) might present a potential alternative for individual with PD or dementia with high levels of physical frailty and cognitive impairment (Taylor et al., 2012).

Potential of Tai Chi (TC), a mind body exercise:

TC is a mind-body exercise that combines a sequence of slow, smooth motions with calm, deep breathing while standing (Freeman & Lawlis, 2001; Wang et al., 2004). It combines breathing, stretching, and vital energy (such as- prana, apana, samana, udana and vyana) and considered as a suitable alternative treatment for dementia and PD patients (Wang et al.,2017). It focuses on appropriate posture, alignment of the spine, and body weight shifting, which can help patients adjust their neuromuscular or musculoskeletal impairments. The slow, even, and continuous flowing movements of TC help patients enhance their sensory awareness, control their balance and stability, and improve their mobility and postural instability problems (Li, F et al., 2007). Furthermore, TC practice demands constant concentration, coordination, and integration of the motor and language systems (Lin et al., 2019). On the other hand, it also helps to lower stress and anxiety

(Abbott & Lavretsky, 2013; Jiang et al., 2016). Therefore, TC is a promising exercise intervention for older adults with balance and cognitive disorders.

However, inattention and executive impairment are frequently found to be associated with physiological aging and dementia. Therefore, it is not always easy for PD and dementia patient to learn traditional TC due to the excessive physical and mental demands of certain movements. It is, therefore, evident that a simplified, easy, safe, and enjoyable TC program tailored to the movement limitations inherent in patients with PD and dementia is needed.

Seated Tai Chi (STC), which first emerged in the 1990s, is a popular derivative form of traditional TC. It has short forms (e.g., 10-form and 12-form), which reduces the movements of the lower limbs and allows people to practice the movement in a sitting position. STC breaks through the tradition that TC can only be played in a standing position. It could enhance the control over shifting body weight among different posture directions and improve the sensorimotor coordination involving the head, eyes, hands, and trunk (K. Y. Lee et al., 2015). It could also help participants to control their body movements in a sitting position without incurring much risk (Leung & Tsang, 2008). STC has the potential to improve executive function and attention in individuals with dementia (Lam et al., 2018). STC found to be more accessible, feasible and acceptable for individuals with PD as it required less space and could be performed while seated (Cheon et al., 2017).

Patients must often visit a rehabilitation facility to undertake TC exercises as directed by physical therapists. However, this may occasionally be an issue for a patient who lives in the suburbs because transportation takes more time and money. Furthermore, if a physical therapist is responsible for multiple patients at the same time, the quality of each patient's personalised therapy may decrease. Hiring a home therapist is one approach, but it is not always economically practical. Considering the challenges in performing exercises faced by these populations, implementing exercises that involve the use of technology, such as virtual reality-based Tai Chi (VRTC) exergaming, has some advantages over human-guided exercise where the patient can follow the directions of a digital avatar to undertake rehabilitation exercises or training at home daily (Ribeiro et al., 2021).

Exergaming and its benefits:

The terminology of exergaming is used to describe activities that involve whole-body movement to improve health, physical fitness, and coordination, combining physical activity with gameplay. It can be used as an individual or group activity and help people to engage in movement activities. Exergaming has the potential to encourage older adults to be physically active. There are research focuses on the potential health benefits of using exergaming in healthy seniors and for the rehabilitation of motor impairments, rehabilitation after stroke, and balance training, as well as the cognitive benefits of gamification for older adults to improve their physical activity levels (Holden, 2005).

Several studies have used gaming systems such as Nintendo Wii, Microsoft Xbox with Kinect sensor (Microsoft Corp., Redmond, WA, USA), to enhance physical activity in older adults (Clark & Kraemer, 2009; Harley, Fitzpatrick, Axelrod, White, & McAllister, n.d.). These studies concluded that older adults found these games as motivation to be physically active and improved the quality of social contact between the participants (Wollersheim et al., 2010).

Exercises that utilize an exergame offer several benefits over human-guided exercise, especially considering the difficulties experienced by individuals with PD and dementia. The integrated stimulation of physical and cognitive functions is one advantage of the current generation of video games. In addition, they have been demonstrated to improve game performance and learning of virtual tasks with transference to actual conditions (Mirelman et al., 2011). Exergaming also gives knowledge of performance and an understanding of the consequences of each game.

Types of Exergaming applications (Mhatre et al., 2013):

1. Motion sensing devices- Wii Fit, Microsoft Kinect, and PlayStation games

2. Mobile application that uses GPS- geocaching; and

3. Mobile Specific equipment such as a treadmill and a stationary bicycle with a digital video image.

Among these different types of consoles, participants with cognitive and balance impairment often need assistance while exercising with the Wii Fit (Legouverneur et al., 2011). Unlike the Nintendo Wii, the Kinect can track and evaluate different gestures using an infrared camera, eliminating the need for participants to operate any input device. Balance-based exercise training using Kinect sensor is valuable, safe and has more significant impact on postural stability and functional balance than conventional balance training among persons with PD (Wang, Cheng, and Yang., 2016a; Pompeu et al., 2014). Hence, the benefits of a Kinect-based system in dementia and PD population can be summed up as follows:

1. Simple setup—no additional physical equipment is required.
2. Safety—no additional trip hazards.
3. Affordable—the Microsoft Kinect is a widely available consumer device; and
4. Reasonably accurate—enables whole-body tracking of participants' movements (Clark et al., 2012; Galna et al., 2014).

Moreover, virtual reality based Tai Chi (VRTC) exergaming utilizing Kinect, has several benefits on cognitive and physical abilities in older persons with cognitive impairment (Hsieh et al., 2018). Incorporating STC in virtual reality will be an innovative invention for performing TC exercise because it can potentially have positive effects on depressive symptoms, heart rate, and social domain of quality of life among people with impaired physical mobility (Zhao et al., 2021).

In conclusion, individuals with PD and/or dementia often experience higher levels of frailty and balance impairment, leading to institutionalization, hospitalization, and shorter mortality. Exercise, particularly TC, has effectively improved this patient population's physical and cognitive condition. STC, a modified version of TC that involves less low limb movement is particularly suitable for those with standing difficulties and may reduce the risk of exercise-related injuries. Unfortunately, individuals with PD and/or dementia often struggle to adhere to their regular exercise routine. However, virtual reality-based exercises, such as Kinect exergaming and specifically Virtual Reality Tai Chi (VRTC) exergame, have the potential to provide a virtual trainer that offers real-time exercise performance feedback to the patient from a convenient location. This can potentially improve patient adherence and facilitate exercise interventions in this population.

Study purpose:

This pilot study aimed to determine whether people with mild dementia or PD might benefit from using STC exergame. To achieve this, we used a mixed-methods research design to evaluate the feasibility, acceptability, and usability of a STC exergame among frail older adults with mild dementia or PD. The purpose was to explore participants' perspectives of enjoyment, intention to use, and appropriateness and acceptance of this technology.

We sought to answer the following research questions:

1. What are the feasibility, acceptability, and usability of implementing two consecutive sessions of seated TC exergame for frail older adults with mild dementia or PD?

2. What are the perceptions and performance levels of frail older adults with mild dementia and PD after participating two consecutive sessions of seated Tai Chi exergame with emphasis on balance and mindfulness?

Significance of the study:

The anticipated goal of this study was to determine whether frail older adults with mild dementia or PD could easily adopt, accept, and employ a STC exergame.

This research may provide opportunities for frail older adults to engage and interact in Kinect-based exercise programs. STC, if found to be feasible, may encourage frail people with PD and/or dementia to perform exercise regularly. Basic TC movements in the virtual world may become an effective alternative to conventional exercise to facilitate physical exercise with minimal supervision. A positive intention to utilize the STC exergame may lead to increased adherence to exercise, increased confidence levels, and thus improve balance and strength. In turn, it may have potential benefits to decrease the risks of falls, reduce frailty levels, and improve the physical and mental well-being of frail people living with PD and/or dementia.

Evidence generated from this study will help to provide baseline data to support the use of STC exergame for larger population in a safe environment to promote physical and mental well-being. Participants' perceptions will help stakeholders determine if applying

STC exergame in various healthcare settings, including long-term care, retirement communities, ambulatory care settings, rehabilitation settings, and homes would be beneficial.

Chapter 2: Literature Review

The literature review was conducted to explore the existing literature related to the feasibility, acceptability, and usability of STC exergaming among frail older adults with Mild dementia or PD. Methods for the review, including the inclusion and exclusion criteria, search strategy, and data analysis methods, along with the findings, are presented below.

Literature review method:

A two-step literature search was conducted starting in September 2020 regarding VRTC, explicitly STC. The initial search sought out published literature reviews from January 2000 to June 2022. Literature was gathered as much as possible while considering how rapidly technology advances. Hence, literature published throughout the previous twelve years (2010-2021) were given priority to provide the most recent and updated information about TC exercise and the associated technology application.

The following search terms were used to conduct the literature search. Search terms included “fall,” “virtual reality,” “VR”, “Kinect exergame”, "exercise," "elderly," "Parkinson's Disease," "dementia," "cognitive impairment," “frail”, "Tai Chi," and "exergame" were used interchangeably with the Boolean operators (AND, OR) in the databases. Besides, we used the keyword "elderly" along with "seniors" and "older adults" to ensure that we captured the target audience.

Two internet search strategies were used, which included:

a. Database searches (such as Pubmed, Medline, and ResearchGate) to obtain scholarly articles and
b. internet searches (https://www.parkinson.ca/, https://www.canada.ca) to retrieve the relevant Canadian statistics related to the disease conditions.
c. We considered the title and abstract (if available) relevant for review if we find them related to the topic.

First, 56 studies were selected based on reading their titles and abstract using the database searches as described above. Then the duplicate studies were removed from the database search strategies (n=10). Next, the abstracts were examined from the remaining 46 selected studies in step one and screened based on the specific inclusion/exclusion criteria. The inclusion criteria to screen literature consisted of a sample population of older adults aged 55 years of age and above with PD and/or dementia, written in English, and recently published literature (from January 2000 to June 2022). This criterion helped to identify the TC/STC intervention using exergaming, such as a fall prevention exercise program for frail older adults with PD and/or dementia. The list of inclusion-exclusion criteria with data extraction details is presented in Appendix J.

Literature review themes:

Total of twelve literature were reviewed and three key themes were identified to illustrate the impact of STC exercise and the application of Kinect-based exergame in dementia and PD care. The three themes are-

1. Positive impact of STC on balance, coordination, and cognition

2. Kinect-based exergames are feasible alternatives for regular exercise, and

3. Positive effects of STC using Kinect-based exergaming on balance and cognition.

1. Positive impact of TC and STC on balance, coordination, and cognition:

Several studies from Table 2-1, have shown that TC and STC exercises have positive effects on various aspects of physical and mental health in different populations. TC has been found to improve balance, reduce falls, increase muscle strength, enhance cardioprotective effects, and benefit physical and social functions in individuals with PD and long-term care residents (Gao et al., 2014; Lin et al., 2019). STC exercises have been shown to improve sitting-related sequential weight shifting, standing-based maximum reaching distance, eye-hand coordination, and balance in older individuals with cognitive impairments (Lee et al., 2014; Lu et al., 2009). TC has also been found to improve the quality of life, heart rate, and depressive symptoms in long-term care residents (Hsu et al., 2015; Zhao et al., 2021).

These studies limitations include a high dropout rate due to lack of interest and transportation issues, insufficient information about the STC training, the absence of a control group to compare intervention effects, insufficient details about participants' criteria and training, and no long-term follow-up to assess the sustainability of TC's effects over time.

For instance, Gao et al. (2014) found that TC improved the Berg Balance Scale scores and reduced falls and fall duration in individuals with PD. Similarly, Lee et al. (2014) discovered that a 12-form STC routine improved sitting-related sequential weight shifting and standing-based maximum reaching distance among older adults. STC exercise has also been found to increase muscle strength, improve coordination, enhance cardioprotective effects, and benefit physical functioning, role limitations, and social functions.

Moreover, the quality of life, heart rate, and depressive symptoms were all found to improve with TC in long-term care residents (Hsu et al., 2015; Zhao et al., 2021). Additionally, Lu et al. (2009) investigated the impact of STC on eye-hand coordination in frail older individuals and found that the STC group made fewer errors in accuracy in index finger-pointing task and retained part of their pre-training response time performance. Similarly, Lin et al. (2019) found that TC improved balance and rhythmic forward-backward shift test performance in older individuals with cognitive impairments, such as Alzheimer's disease and mild-to-moderate dementia.

Overall, TC, especially STC appears to be a promising exercise intervention for individuals with cognitive and physical disabilities. However, more research is needed to examine its feasibility, usability on various patient populations and its long-term sustainability as a form of exercise intervention.

Table 2-1: Positive impact of STC on balance, coordination, and cognition

Author	Country	Type of study	Sample size	Technology	Institution	Outcome	Strength	Weakness
Gao et al (2014)	China	Single blinded randomized control trial	76 PD Patients over 40 years old, able to walk independently and fell at least one time.	24-form Yang style Tai Chi exercise for 60 minutes each time, three times a week and lasted for 12 weeks.	A hospital and general community	- Improved Berg Balance Scale (BBS), - Reduced fall - Reduce time of fall	strong study design (RCT), large sample size, and measured both balance and fall prevention outcomes.	Frailty included: No Seated Tai Chi: No, Population region: Asia, Only included participants with Parkinson's disease, dropout was seen due to lack of interest and transportation issue.
Lee et al (2014)	Hong Kong	randomized controlled trial	29 older adults in intervention group	A 12-form sitting Tai Chi, 3 months, with 3 sessions per week (a total of 36 sessions)	residential care facilities	significant improvement in their sequential weight shifting while sitting and maximum reaching distance from a sitting position.	measured both balance and muscle strength outcomes.	Frailty included: No Seated Tai Chi: No, Population region: Asia, Detail information about the STC training was not provided.

								No follow up regarding sustainability of the intervention was taken.
Hsu et al. (2015)	Taiwan	Randomized controlled trial.	60 long-term care residents	40 min of STC exercise, three times a week for 26 weeks by a certified trainer.	long-term care facility	significantly lower depression symptoms and higher scores in Quality of life.	Measured a range of physical and mental health outcomes.	Frailty included: No Seated Tai Chi: Yes, Population region: Asia, Did not have a control group to observe whether improvements were due to the TC intervention.
Lu et al (2009)	Hong Kong	Clinical trial	40 frail older adults in intervention group	STC training by physiotherapists, 36 sessions (1h/session, 3 sessions/week).	Rehabilitation centre	TC group achieved less errors in accuracy in index finger-pointing task, also maintained some performance in reaction time as pre-training.	Observed eye-hand coordination in frail older adults.	Frailty included: No Seated Tai Chi: Yes, Population region: Asia, Enough information regarding participants' criteria and training was not provided.

Lin et al (2019)	Taiwan	case-controlled study	26 older adults' persons with AD and mild-to-moderate dementia were enrolled but 11 completed the training course.	6-form TC was originally designed for 8 weeks, two times per week, and 45 min per session.	community dwellers	Significant improvement in balance and rhythmic forward–backward shift in the Tai chi group.	This study focused on the effects of TC on both balance and cognition.	Frailty included: No Seated Tai Chi: No, Population region: Asia, Did not have a long-term follow-up to see if the effects of TC were sustained over time.

Table 2-2: VR Kinect-based exergames are feasible alternatives for regular exercise.

Author	**Country**	**Type of study**	**Sample size**	**Technology**	**Institution**	**Outcome**	**Strength**	**Weakness**
Mendez et al (2015)	USA	mixed methods design	5 people with dementia	Head Mounted Display-Virtual Reality (HMD-VR)	hospital specialising in progressive neurological	(HMD-VR) was tried and accepted by people with	Used both qualitative and quantitative methods to	Frailty included: No Seated Tai Chi: No, Population region: North America, Small sample size, conducted in an inpatient psychiatric setting, Safety issues or adverse

					conditions.	dementia. People with dementia experienced more pleasure and increased alertness using HMD-VR exposure.	evaluate the feasibility and acceptability of the intervention.	event was not discussed.
Legouverneur et al (2011)	Unavailable	Usability study	31 older adults with mild-to-moderate cognitive impairment aged between 75 and 90 years.	Wii mote	day care centre	- Individuals in the AD and the MCI groups needed more assistance.	relatively large sample size of 31 participants. The study uses both qualitative and quantitative methods	Frailty included: No Seated Tai Chi: No, Population region: Unavailable, Only includes patients with mild cognitive impairment and Alzheimer's disease, limiting the generalizability of the findings.

							to evaluate the usability of Wii Sports.	
Pompeu et al (2014)	Brazil	Randomized control trial.	7 patients (six males, one female) with Parkinson's disease (Hoehn and Yahr Stages 2 and 3).	Microsoft Kinect™, Fourteen 60-minute sessions, three times per week, playing four games of Kinect Adventures.	Rehabilitation Center	Improvements in scores and in the 6-minute walk test.	The study uses a randomized controlled trial design with a relatively large sample size of 40 participants.	Frailty included: No Seated Tai Chi: No, Population region: South America, Did not compare the effectiveness to other forms of training or interventions. The study only includes patients with Parkinson's disease, limiting the generalizability of the findings.
Manera et al (2016)	France	Feasibility study	30 participants with MCI and 30 participants with dementia	Highly realistic image-based rendered VR	Research centre	MCI and dementia reported to be highly satisfied and interested in the VR related	The study uses both qualitative and quantitative methods to evaluate	Frailty included: No Seated Tai Chi: No, Population region: Europe, Investigates only the feasibility of using the technology and does not investigate the potential therapeutic benefits of using the technology.

						task, and they reported high feelings of security, low discomfort, anxiety, and fatigue.	the feasibility of using the technology.	

Table 2-3: Effects of Kinect based exercise on balance and cognition.

Author	Country	Type of study	Sample size	Technology	Institution	Outcome	Strength	Weakness
Hsieha et al (2018)	Taiwan	clustered quasi-experimental clinical trial design	60 older adults with CI.	Xbox 360 Kinect (Microsoft Corp., Redmond, WA, USA)	Long term care facility	significant improvement in the 6-min walk test, 30-s sit-to-stand test, functional reach, 5-m gait speed, and abstract. thinking and judgment	Utilized a VRTC exercise, which provides an innovative and engaging way of delivering rehabilitation to older adults with cognitive impairment.	Frailty included: No Seated Tai Chi: No, Population region: Asia, The follow-up period was short, done only on older adults with cognitive impairment, significant dropout observed (27%) in intervention group
Kayama et al (2014)	Japan	Case Control Study	41 older adults' individuals (TG: n=26, CG: n=15)	Dual-Task Tai Chi (DTTC), using Microsoft's motion-capture device Kinect	Community-dwelling	DTTC training was effective in improving executive cognitive functions and has a positive	Utilized a DTTC intervention, which addresses both physical and cognitive	Frailty included: No Seated Tai Chi: No, Population region: Asia, The study did not include a long-term

						impact on dual task ability and the prevention of falling.	aspects of fall prevention. The study had a randomized controlled design, and the outcome measures were reliable and valid.	follow-up to assess the sustainability of the intervention. No information regarding adverse event.
Neubauer, N. A., Mooney, C. M., Allegrante, J. P., & von Hahn, K. (2017)	USA	Feasibility study	10 participants with mild to moderate dementia who can walk independently	Homebased Kinect TC	Home settings	Reduction in depression and improvement in physical activity levels.	No adverse event during the intervention and follow up	Frailty included: No Seated Tai Chi: No, Population region: North America, Drop out rate high (33%), Lack of information related to technology

2. **Kinect-based exergaming are feasible alternatives for regular exercise**

Virtual Reality and exergaming have emerged as potential alternatives to human-guided exercise to improve balance, functional mobility, and quality of life for older adults, individuals with cognitive impairment, and neurological conditions such as dementia and PD (summary of the study findings are shown in Table 2-2).

The use of Head Mounted Display-VR in an inpatient psychiatric care setting was positively perceived by patients with dementia, resulting in increased happiness and self-awareness (Mendez et al., 2015). Individuals with cognitive disabilities could safely and effectively use wireless controllers and play video games on various consoles such as the Nintendo Wii, Xbox Kinect console (Legouverneur et al., 2011, Pompeu et al., 2014). Moreover, VR-based exergaming has been shown to increase adherence to cognitive training and provide a novel and immersive way to stimulate patients' senses and promote their engagement in activities (Manera et al., 2016).

However, these studies included small sample size, conducted in limited settings, safety issues not discussed, and limited generalizability due to the inclusion of specific patient populations or lack of comparison to other interventions. Additionally, one study only investigates the feasibility of using technology, without exploring potential therapeutic benefits.

Mendez et al. (2015) found that the use of Head Mounted Display-Virtual Reality (HMD-VR) in an inpatient psychiatric care setting was positively perceived by patients with dementia, resulting in increased happiness and self-awareness. Legouverneur et al. (2011) reported that individuals with cognitive disabilities could learn to use wireless controllers and play video games on the Nintendo Wii console, and Pompeu et al. (2014) demonstrated that PD patients could safely and effectively train with the Kinect. VR-based training has been shown to increase adherence to cognitive training and provide a novel and immersive way to stimulate patients' senses and promote their engagement in activities, as reported by Manera et al. (2016). These studies collectively demonstrate the potential of technology-based interventions to improve the physical and cognitive functions of individuals with neurological conditions and cognitive impairment.

3. Positive effects of Kinect-based exercise on balance and cognition:

The use of Kinect-based exercise has been investigated in several studies as shown in the table 2-3, for its impact on balance, gait, and cognition. Hsieh et al. (2018) conducted a clustered quasi-experimental clinical study with older adults with cognitive impairment (CI) from long-term care facilities. They found that VRTC exercise using the Kinect improved both cognitive and physical abilities in older persons with CI. Similarly, Kayama et al. (2014) used Microsoft's motion-capture system Kinect to create a new game concept called Dual-Task Tai Chi (DTTC), which enhanced executive cognitive abilities and improved dual-task competence and the capacity to avoid falling in older persons living in communities. Lee et al. (2018) demonstrated through their Kinect-based rehabilitation system that VR may assist patients with impairments to obtain the rehabilitative impact as utilizing expensive rehabilitation equipment. Lee et al. (2018) demonstrated that a Kinect-based rehabilitation system has the potential to be a cheaper alternative to expensive rehabilitation equipment.

Shih et al. (2016b) conducted a randomized control trial using the Kinect sensor among people with PD and found that balance-based exergaming training had a more significant effect on postural stability and functional balance than conventional balance training. Neubauer et al. (2017b) conducted a large-scale study using a home Kinect-based Tai Chi system (K-Tai Chi) to determine its effect on the physical and mental health of persons

with dementia. K-Tai Chi was found to be user-friendly and effective in reducing depression and improving physical activity levels.

However, these studies include a short follow-up period, a significant dropout rate between 27% to 33% in the intervention group, no long-term follow-up to evaluate the sustainability of the intervention, and inadequate information related to technology and adverse events.

Overall, these studies suggest that Kinect-based exercise has positive effects on some cognitive and physical functions and improvement of balance. They also indicate that Kinect-based exercise may offer cost-effective and user-friendly alternatives to traditional exercise programs for older adults and those with balance impairments.

Lessons Learned from the Literature Review:

This literature review aimed to evaluate the feasibility, usability, and acceptability of VRTC exergaming for people with neurological conditions such as PD and dementia. We must, however, widen the scope of the literature evaluation because there needs to be more research conducted on the viability of VRTC exergaming. Only 5 out of the 12 publications addressed Kinect exergaming (Hsieha et al., 2018; Kayama et al., 2014; Lee et al., 2018; Neubauer et al., 2017; Pompeu et al., 2014), indicating that the need for more studies to explore the feasibility of the technology before it can be fully utilized to enhance balance

and cognitive stimulation. It should be noted that grey literature seldom mentions VRTC exergaming, suggesting the importance of having more research conducted in this study area. Moreover, Kinect-based TC is a relatively new emerging exercise platform and there is a need for more research to examine its potential impact of both the physical and cognitive function of older adults in the context of frail older adults with PD and dementia, especially in the Canadian context.

Based on the findings from the literature review, VR exergaming encourages older adults to exercise regularly within an in-home setting and has the potential to be a cost-effective alternative to instructor-led exercise programs (Mendez et al., 2015; Legouverneur et al., 2011; Pompeu et al., 2014; Manera et al., 2016). With an alarming rise in PD and dementia, the financial burden for patients associated with medication costs will also be increased. So, there is a need for more attention towards nonpharmacological approaches such as physical exercises to mitigate the economic burden for older adults. This research will advance our understanding and provide insight into the feasibility of VRTC exergame among frail older adults with PD and/or dementia.

Most of the research (n=5) discovered from our literature review were randomized control trials (Hsu et al., 2015, Lu et al., 2009, Gao et al., 2014, Lee et al., 2014 and Lin et al., 2019). Only Mendez et al., 2015 used a mixed-method design. There needs to be greater research adopting mixed-methods design, with qualitative methodology to identify participants' perceptions and experiences of using the technology.

On the other hand, it was noted that various studies employ VR technology using different approaches. Because VR gadgets like the Wii fit (Legouverneur et al., 2011) and Kinect (Hsieha et al., 2018, Kayama et al., 2014 and Lee et al., 2018) have a variety of uses and features, it was difficult to conclude which one is suitable and appropriate for utilization among frail people with PD and/or dementia.

Also, the level of appeal and engagement with VR technology may affect how well VR exergaming could work. Some people with PD and dementia can find utilizing VR equipment overwhelming or perplexing, which would lower their motivation and level of participation in VR exergaming. The stages of dementia may also impact a person's capacity to utilize and benefit from technology. Therefore, developing a simplified TC exergame such as STC, is crucial to provide a simple method of learning and practicing TC for people with balance and cognitive impairment (Lee et al., 2014; Lin et al., 2019).

Furthermore, to our knowledge, no research has been found that has investigated the feasibility and usability of STC exergaming application for frail older adult with mild dementia or PD. One reason for this gap might be the lack of knowledge and awareness among older adults as well as their caregivers regarding TC exercises, VR, and the potential of TC exergame applications in improving balance and cognition.

Overall, it is identified from the literature review that there is a knowledge gap concerning the use of mixed methods approach to explore the feasibility and potential utilization of STC exergaming. Future research is necessary to explore the feasibility, usability, and efficacy of VRTC applications for frail older adults with PD and/or dementia. Such research could provide valuable insights into the development of targeted exercise interventions and programs using exergaming to enhance the physical and cognitive well-being of people with neurological conditions and cognitive impairment.

Chapter 3: Methodology

Study design

This research study adopted a mixed-method approach. Mixed methods research has various names and definitions (Fiorini, Griffiths, & Houdmont,2016). Johnson, Onwuegbuzie, & Turner (2007, p. 123) defined mixed method research as:

". . . the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration."

Researchers who see inquiry as an approach to solving problems are referred to as pragmatists and often choose practical problem-solving research methods (Maddux & Donnett, 2015). Pragmatists are receptive and try to blend worldviews and research methods to solve a problem (Schutz, Chambless, & DeCuir,2004; Schutz, Nichols, & Rodgers,2009). With the worldview of pragmatism, these researchers are willing to use multiple approaches to solve problems. There is a tendency for these researchers to approach inquiry from a universalist perspective, which suggests there might be some basic" truths"; however, those truths and related human processes tend to be influenced by the contexts (Berry, Berry, Poortinga, Segall, & Dasen,2002; Zusho & Clayton,2011). This pragmatic approach guides the researchers in choosing the methodology best suited to address the research problem.

For this study, an embedded mixed method design was used, a type of design in which one data set provides a supportive, secondary role in a study based primarily on the other data type (Creswell, Plano Clark, et al., 2003). The premises of this design are that a

single data set is not sufficient, that different questions need to be answered, and that each type of question requires different types of data. The quantitative data about the pilot testing of the VR-based STC exergame was initially collected, followed by qualitative data to explore the user experiences and interaction with the intervention. The purpose of using this mixed methods design is to gain the depth and breadth to achieve a better understanding of the study topic and to develop a more comprehensive picture of the phenomenon of interest that could not have been achieved by collecting quantitative or qualitative data alone. The quantitative research aimed to examine whether the seated Tai Chi (STC) is easy to adopt by the participants related to comfort, learning of technology use, adverse events, and performance scores. The qualitative research was conducted to gain an in-depth detailed description of participants' perspectives related to their experience and satisfaction with TC exergame.

The purpose of this mixed-methods study is to answer the following research questions-

1. What are the feasibility, acceptability, and usability of implementing two consecutive sessions of seated TC exergame for frail older adults with mild dementia or PD?

2. What are the perceptions and performance levels of frail older adults with mild dementia and PD after participating two consecutive sessions of seated Tai Chi exergame with emphasis on balance and mindfulness?

Research framework:

This study used the "Fit between Individuals, Task, and Technology" (FITT) framework to guide the research. The FITT framework suggests that implementing new technology related to healthcare systems requires a fit between the user, the technology, and the task

that is undertaken (Gray *et al*, 2016). The FITT framework was implemented to assess the feasibility, with a usability analysis to evaluate the exergame.

The WHO (WHO, 2016) defined feasibility as “assessing whether the digital health system works as intended in a given context.” This is strongly related to the FITT model's objective to assess the ability of a technology to be utilized by the users. On the other hand, The WHO (WHO, 2016) defined usability as “assessing whether the digital health system is used as intended.” In this research, ***usability*** was determined by the success rate of completion, improvement in task score, learning time, and users’ satisfaction.

We evaluated feasibility and usability regarding safety, user-friendliness, and any adverse event during the exercise. Acceptability was evaluated in terms of ease of use, enjoyment, satisfaction, and motivation to continue in the future.

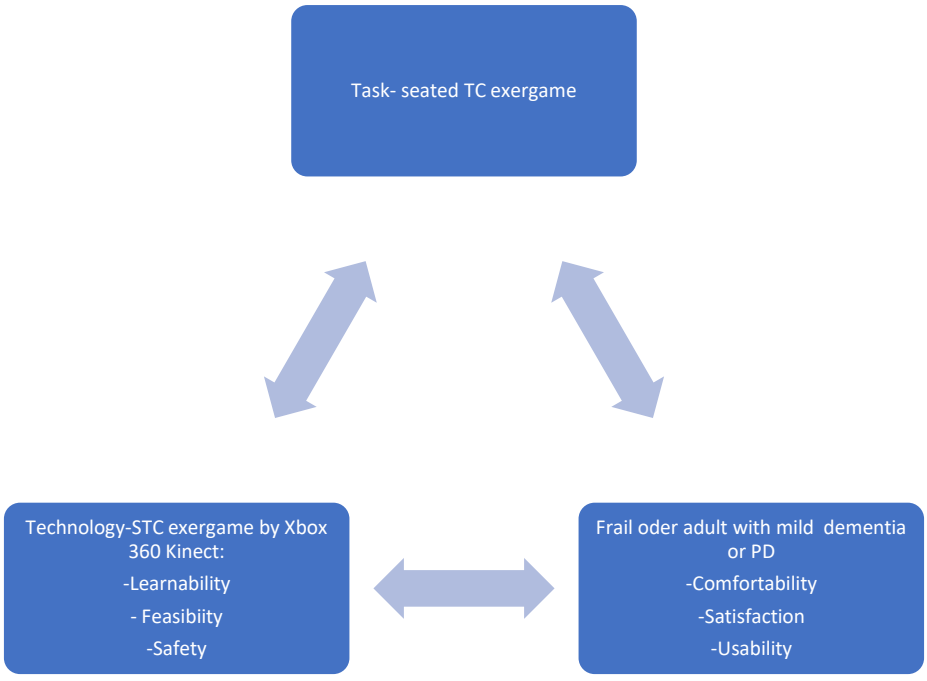


Figure 3.1: Predicted Model (Based on FITT framework)

Sampling:

Participants:

Seven participants with mild dementia or PD from Ontario Shores Centre for Mental Health Sciences and Mood Clinic were involved in the study. This study was a pilot study where a smaller sample size was justifiable to evaluate the usability of user experiences.

Inclusion criteria for study participants:

- Participants with mild dementia or PD (identified by study personnel or self-identified through recruitment material) at or above 55 years were selected. This age group was considered because the target population was older adults with early stages of mild dementia, irrespective of the stages of PD.
- History of at least one fall or near fall in the last year.
- A Fried's Frailty score of three or more to indicate the higher level of frailty. The score was assessed by the frailty scale which was completed by health personnel of Ontario Shores.

Although there is no universal gold standard definition of frailty, Fried Frailty Index was used in this study to guide the understanding of the concept of frailty. The criteria and frailty scores are described below.

Frailty score:

The five criteria included in the Frailty Index are:

1. weight loss of >10lbs in the past year,

2. Maximal hand-grip strength,

3. Time to walk 15 feet at the usual pace,

4. Self-reported inactivity, and

5. Self-reported exhaustion (Roland et al., 2012).

One point is scored for each positive feature. Consequently, patients were stratified as non-frail (score 0), pre-frail (score 1-2), or frail (score ≥3) (Fried *et al.,* 2001)

- A Mini-mental status score (MMSE) of 18 to 24 suggests mild cognitive impairment which was assessed by health personnel of Ontario Shores.
- Able to provide informed written consent.
- Can speak English.

Exclusion criteria for the participants:

- Those who had severe visual or auditory abnormalities.
- Those who had moderate or severe dementia.
- Any recent injury that prevents participation in exercises.
- Exercise contraindications such as recent myocardial infarction or electrocardiography changes or hip replacement following fractures, complete heart block, acute congestive heart failure, unstable angina, and uncontrolled hypertension.

Recruitment:

After receiving approval from the Research Ethics Board (Ontario Shores Centre for Mental Health Sciences) (file #21-016-B), the study personnel at Ontario Shores identified potential participants to support the recruitment process. Promotional flyers and authorized emails were sent to facilitate recruitment.

The written consent form (appendix D) was distributed before the research briefing. This consent form provided participants with detailed information about the study to make informed and voluntary decisions for study participation. Interested participants were invited to participate in the exercise session and the interview at a convenient time and predetermined place.

Participants recruitment was conducted via study personnel in the Geriatric Dementia Unit, Geriatric Psychiatry Unit, Geriatric Transitional Unit, and Outpatient Geriatric Mental Health clinic at Ontario Shores Centre for Mental Health Sciences to support the recruitment process. Participants were made aware of the study-by-study personnel using the recruitment flyer (Appendix A). Participants expressed their interest in study participation via the recruitment flyer's contact information (phone or email). Then the researcher connected with the interested participants to explain the research study's purpose, procedure, and significance by telephone or email.

Interventions:

Apparatus:

The Xbox 360 Kinect (Microsoft Corp., Redmond, WA, USA) gaming console was utilized, and the Kinect sensor was mounted around one meter above the ground. The display was placed in such a distance, so that the participants can comfortably visualize and follow the instructions. Each player's motion was recorded by a Kinect sensor on the console, and the picture was then projected onto a huge flat screen. The activity was done while the participants were seated. The individual also had access to a wheelchair setup if necessary.

Exercise Regimen:

"The Your Shape Fitness Evolved software, Zen" is the name of the program that was utilized. These includes motions adapted from yoga and Tai Chi-based fitness regimens. Also, this program employs gradual, continuous motions that are ideal for weight-bearing, weight-shifting, coordination, and body trunk rotation in both young individuals and senior citizens (Wolf et al., 1997). The patient did not need to be in a standing posture to adhere to the ethics compliance to address safety considerations. or wear any type of VR gear to complete the exercise regimen.

In order to complete this exercise, one must sit up straight with their toes pointing forward, the arms at their sides, with normal breathing. Later, using a VR-based exercise game, players had to perform various motions. For instance, while maintaining an upright trunk position, participants had to simultaneously lift their arms to shoulder level. They then maintained a healthy trunk posture while abducting their right (or left) arm to shoulder level with elbow flexion at around 90 degrees. Next, they had to sit down and cross their arms in front of their chest. The facilitation of neuromuscular body patterns and the emphasis placed on reciprocal movements are made possible by these motions (Kim, J., Son, J., Ko, N., & Yoon, B., 2013).

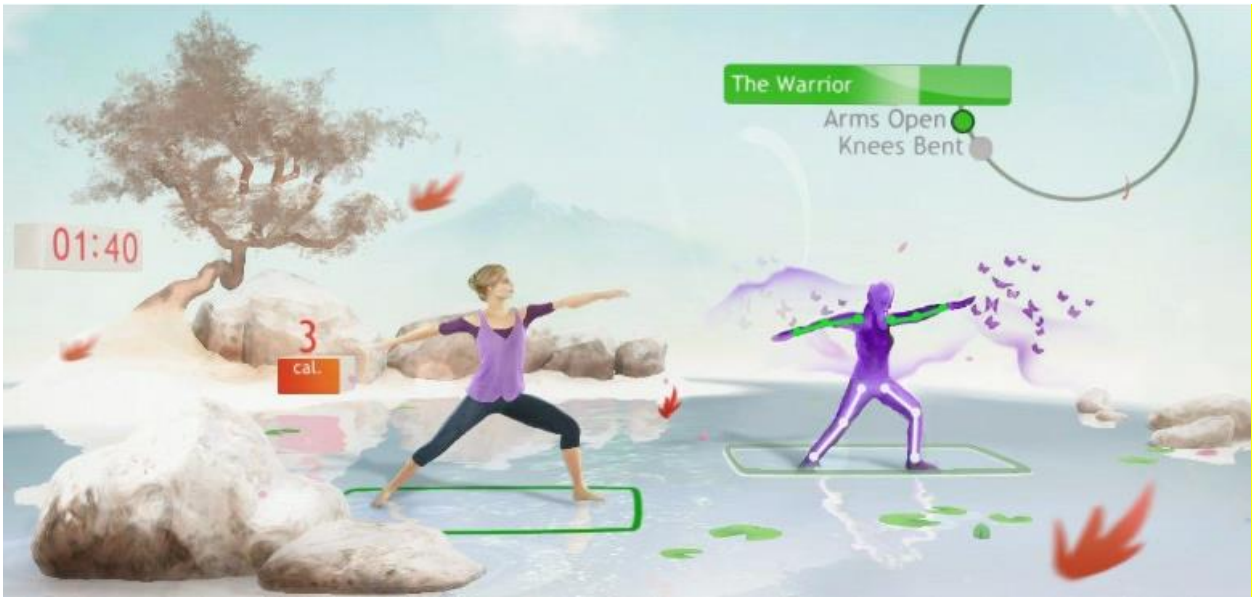


Figure 3.2: Tai Chi Session from “Your Shape Fitness Evolved Software, Zen”

Figure 3.3: The participants received a score based on how well they could follow the movements (Lee, J. D., Hsieh, C. H., & Lin, T. Y., 2018)

This program has a split screen that displays the participants' captured body position in real time. To simulate the participant's basic skeletal form, white lines are superimposed on the participant's screen for the arms, trunk, and legs. When the participant's specific body parts were detected in the right positions, they glowed green. The participant's motions were monitored by the motion capture sensor and body tracking technology, and they were able to evaluate their workout at the completion of the exercise game.

Participants were rewarded for doing the exercises correctly using a performance score system. If they made erroneous motions or moved too quickly or slowly, the program would modify their performance score. A virtual instructor offered both verbal and visual feedback on each participant's activity, ensuring that each motion was carried out properly. They had constant access to the virtual instructor, who motivated them to earn the highest possible grades. In addition to the virtual instructor, a medical professional and a researcher were present to monitor and support the patient as needed.

At the start of the session, participants received instructions on how the motion capture sensor operates. Participants took part in the exercise game in two consecutive sessions. The Levodopa drug was taken by patients with PD around two hours before beginning the activities as the onset of action of levodopa is 20 to 40 minutes, and the duration of effect is 2 to 4 hours after taking medication. The Levodopa drug helps control the Parkinsonian symptoms among patients with PD.

After completing the demographic questionnaire (appendix E), participants played the Tai Chi exercise game for 30 minutes. There were two sets of exercises totaling 15 minutes each, with a 5-minute warm-up before each session, a 5- to 10-minute rest between sessions, and a 5-minute cool-down after each session (The entire procedure includes the exercise sessions, completion of surveys, and qualitative interviews that last approximately 60-70 minutes).

Figure 3.4: Xbox setup for the exercise session

Study Outcomes:

The primary goal of this research was to conduct a feasibility study to evaluate the acceptability, interest, safety, and usability of using STC exergames by frail older adults with mild dementia or PD. The quantitative research aimed to examine whether the STC is easy to adopt by the participants related to comfort, learning time of technology use, reporting of any adverse events, and performance scores. The qualitative research was conducted to gain a detailed description of the perspectives of participants related to their experience and satisfaction with Tai Chi exergame.

Data Collection:

After completing the exercise session, participants were asked to complete a survey questionnaire (Appendix F) regarding their experience using the exergame. The survey

questionnaires consisted of some Likert scale type question ranking from one to five. The task assessment survey (Appendix H) was conducted by the researcher to evaluate their performance (such as- performance score, adverse events, learning time etc.). The two sessions of exercises were evaluated by comparing the two performance scores (Appendix H). It took approximately 10-15 minutes to complete the surveys.

After completing the survey, a short (15-20 minutes) one-to-one interview was scheduled for the qualitative research (Appendix G). The interviews were audio recorded.

Data Analysis:

For the quantitative research, data was analyzed using the Dedoose (v. 9.0.62) mixed-methods research software for Windows. Descriptive statistics to describe the participants' general demographic and other characteristics were presented by frequency percentages. Frequency percentage was used for Likert Scale analysis.

Data collection and simultaneous analysis were carried out until data saturation was reached (Polit & Beck, 2020).

A descriptive thematic qualitative analysis was conducted. Descriptive thematic analysis is useful to produce meaningful descriptions of data from qualitative interviews (Bowling & Ebrahim, 2005). The researcher used the following six phases of data analysis in accordance with Braun and Clark's (2006) guidelines:

1.In order to become familiar with the data and gain a thorough knowledge of the participants' lived experiences, the researcher read each interview transcript numerous times as part of the first stage.

2. The researcher reviewed the transcripts in step two and created a code for each transcript before assigning an initial code.

3. The following phase involved creating a codebook to organise the codes, which included transcript straight quotations as well as code descriptions.

4. The fourth phase involved compiling the codes to generate possible themes.

5. The highlighted themes were checked for coherence in the fifth phase, and using a thematic map, they were cross-referenced with the code excerpts and illustrative quotes. To guarantee the authenticity and dependability of the study findings, the themes were then identified and discussed together with the data extracts.

6. The last stage was to create an exploratory summary report regarding the research study's findings.

Scientific rigor:

In qualitative research, scientific rigour is essential and entails transferability, confirmability, and dependability (Lincoln & Guba, 1985).

Transferability refers to the applicability of this study's research findings to a larger study population. In order for the knowledge and results to be useful to the intended users, the study's objective was to determine the usability of the TC exergame among frail older adults with PD and/or dementia, as well as investigating their perspectives and

experiences surrounding the usage of exergame. Although data came from a single institution, the study's findings will have implications for other healthcare settings focusing on our target groups (i.e.. long-term care facilities, community-based and home settings).

The components of neutrality are included in confirmability. Confirmability in a qualitative study can be attained by setting aside the researcher's prior knowledge in order to view the phenomenon from the participant's perspective. The graduate supervisor independently checked the examined data to ensure the veracity of the study findings.

Consistency-related elements are referred to as dependability. In this research study, dependability was attained by external audits carried out by the supervisory thesis committee to assess the accuracy of the research study and its findings, as well as to examine whether the data corroborated the study's interpretations and conclusions.

Role of the researcher:

As a researcher, I conducted the literature review, created the study design, carried out the research study, facilitated the interviews, evaluated the data, and created the final study report. My background as a researcher and my prior lived experiences may have had an impact on these tasks, and therefore researcher reflexivity was carried out throughout the study process.

To develop the relationship with my research participants, I introduced myself, explained my research study, handed out recruitment flyers, called or emailed participants who had expressed interest (the participant list was provided by a staff member in the facility, who

had been assigned to assist with the recruitment process), gave the participant a letter of information, and then conducted the exergame sessions.

Reflexivity of the researcher:

I'm a Bangladeshi medical graduate who worked in clinical practise for three years before moving abroad. During my graduate studies, I had the privilege to work under the supervision of Dr Winnie Sun in other research projects that includes patient with PD and mild dementia. Her deep understanding on qualitative research has great impact on my research endeavours. While working under her guidance along with my previous clinical training led me to believe that dementia and Parkinson's disease are incurable diseases that inflict significant pain for both patients and the people who care for them. I think nonpharmacological treatment offers hope for bettering cognitive function and restoring health equilibrium. I proposed that VR-based TC games may be more advantageous for balance and cognition than other conventional exercises. As a result, I was conscious of and constantly examined my potential biases and held onto my personal beliefs and experiences during the data analysis. This was achieved by practising reflexivity, a form of self-reflection that researchers must engage in in order to become aware of their thoughts, feelings, and behaviours. Reflexivity increased the transparency of the researcher's roles and functions (Darawsheh & Stanley, 2014). I practised reflexivity to ensure the validity of the study's findings. To ensure the credibility of thematic analysis is not influenced by the findings from the literature or by my prior background and experiences, for example, I practised reflexivity during the coding of qualitative data during the analysis and interpretation of study findings.

Ethical Considerations (Risks and Benefits):

Potential Risks:

There was minimal potential for psychological risk associated with this study. The interview/survey questions may trigger memories of the participants' lived experiences of challenges related to their disease management. If any emotional distress arose during the sharing of their experiences, participants were able to take a break and resume the interview if they wished to continue. Also, they had the right to withdraw from the interview if they were not comfortable doing so. If required, participants were advised to consult with counseling and support services- Alzheimer Society of Durham Region Support Group and Hotline, Whitby, Ontario. Their contact information- is (905) 576-2567. They help people living with dementia by providing information, resources, education, support, and counseling.

All the participants conducted these TC movements while sitting down using their upper-body joints (shoulders, elbows, wrists, arms, and head). The lower-body joints (hips, knees, ankles, and feet) were not part of the TC movements. This minimized the chance of any adverse events (such as vertigo risk of fall). A seating arrangement was available with good back support for this purpose. While Tai Chi involves slow movements, the participants may experience minor aches in their hands and shoulder. If there was any physical distress arose during the exercise program, we took a break. Participants rested and continued when they wish to do. Also, a physiotherapist/nurse was available who was not directly involved as a researcher. The role of the physiotherapist/nurse was to monitor

any adverse events during the exercise session and aid the participants at all times during the exercise program. Therefore, the physiotherapist/nurse intervened if the participant required any physical support. All appropriate safety measures were implemented to prevent adverse events, such as the therapist staying close to the participant during the exercise program (less than 1 meter apart) to monitor the participants' movements. The principal investigator and co-investigator were also available during the session.

Also, if the participants were not feeling comfortable performing some movements, they can inform the research team immediately. Then, the movements were adjusted based on their levels of comfort and preferences. Also, participants can withdraw from participating at any time during the session by informing the researchers.

Potential Benefits:

Several studies have shown the benefits of TC and STC for both the physical and mental aspects of people with PD and/or dementia. Nevertheless, limited research has been conducted to evaluate suitable TC movements specifically for frail older adults with PD and/or dementia in a virtual environment.

This research provided the participants with the opportunity to engage in a STC exercise program by interacting with VR. As this exergame offered real-time feedback, the participants received an immediate feedback score on their movements. At the end of the session, the participants received their overall scores about their performance. In the future, if they continue the exercise, this score will help the participants gauge the condition of their upper body posture. A higher/improved score indicated that they could

perform the movement accurately and were able to achieve a better fitness level, while a lower score would suggest otherwise.

This session could be regarded as a trial use of VR technology for the participants if they are looking for a cheaper alternative for daily exercise at home with less supervision (i.e., without the need for an in-person guided professional coach, such as physiotherapist or occupational therapist). Moreover, immediately after completing the STC exergame, some of the participants experienced some short-term benefits, such as feelings of relaxation.

Ethical Considerations (Privacy and Confidentiality):

Confidentiality was ensured by the following procedures:

1. After a pseudonym had been developed, any direct identifiers were destroyed, which took two weeks to do so after data collection.

2. Throughout the study, the study data was only accessible by the researchers named in the Research Ethics Board (REB) application.

3. To safeguard the participant's rights to confidentiality and anonymity, both verbal and written information about the objectives of this study was available throughout the study period. Besides, all data collected was stored in a personal, password-protected laptop kept in a secure location and on Ontario Tech’s Google Drive.

Chapter 4: Results

The study findings are presented in this chapter with outcome measures and illustrative quotes. For the qualitative analysis, themes and sub-themes were described, along with the demographic data of the study sample and survey results post-intervention.

The interview data revealed a total of five overarching themes, some of which had a subtheme supported by descriptive quotes. Additionally, throughout the interview, perceived barriers and potential improvement were explored; these are discussed at the end of this chapter.

Demographic information of study sample:

A total of seven (7) participants were recruited from both Geriatric Transitional Unit (GTU) and Geriatric Dementia Unit (GDU) of Ontario Shores Centre for Mental Health Sciences and Outpatient Mood Clinic for this research study. The participants consisted of patients with mild dementia (n=6) and Parkinson's Disease (n=1).

Among the seven participants who agreed to participate and be interviewed, 57.15% were male (n=4), while 42.85% were female (n=3). The age of the participants ranged from 60-70+ years. Six of the participants resided at Ontario Shores, while one participant was from Mood Clinic. All the participants had PD or mild dementia between 1 to 2 years. No participants had both diseases.

The education level of the participants differed widely, with one participant attended university, four attended college, and the remaining two participants attended high school.

Most (85.7%) of the participants did not have previous experience with VR games. Similarly. 71.42% of the participants did not have experience with Tai Chi, while 28.58% had previous experience.

The feasibility, acceptability, and usefulness of the STC exercise have been explored with these participants through surveys and interviews. Most of the information in the last few interview sessions was repeated from earlier interviews and did not bring further insights into the interview data. This was a sign that I ceased gathering new data because data saturation had been reached.

Table 4.1: Demographic characteristics of the participants

Characteristics, N = 7	
Sex	
Male, n = 4	57.15%
Female, n = 3	42.85%
Age	
55-59, n = 0	00.00%
60-65, n = 2	28.57%
66-69, n = 2	28.57%
70+, n = 3	42.85%
Education	
No formal education, n = 0	00.00%
High school, n = 2	28.57%
College, n = 4	57.14%
University, n = 1	14.28%
Experience with VR games	
Yes, n = 1	14.28%
No, n = 6	85.71%
Comfortable with VR	
Yes, n = 6	85.71%
No, n = 1	14.28%
Experience with Tai Chi	
Yes, n = 2	28.57%
No, n = 5	71.42%
Suffering from diseases for	
One year, n = 2	28.57%

Two-year, n = 5	71.42%
Fall Characteristics	
Near Falls, n = 7	100%
No fall, n = 2	28.57%
Fallers (at least one fall), n = 3	42.85%
Frequent Fallers (>1 fall), n = 2	28.57%
Frailty Score	
Non-frail (score 0)	0%
Pre-frail (score 1-2)	0%
Frail (score ≥3)	100%

Survey results from post-intervention:

The primary goal of the survey is to examine the perceived experience and challenges by the participants after completing the exercise intervention.

User experience related to any adverse events during performance of STC movements:

Each participant acknowledged how simple it was to complete the moves in this STC exercise. While 28.57% of participants agreed with feeling mild pain, the majority of participants (71.42%) disagreed with any experienced pain or discomfort. One participant (14.28%) said they experienced pain or discomfort while playing the exercise game. Those who expressed slight soreness or discomfort were evaluated for additional investigation. Further investigation revealed that the aches or discomfort were only transient. It's probable that this soreness was caused by inadequate physical movements.

The participants indicated that they would be interested in taking part in the STC exercise game between 1-2 times a week for an average of 15 minutes.

User experience related to usability of Kinect exergame:

Among all the participants, 85.70% agreed that the VR exergame is satisfying, safe, and comfortable. Approximately 43% of participants' responses indicated that they agreed that this exergame is easy to operate, while 57% responses indicated that they are neutral with the statements (Figure 4.1).

The majority of study participants (85.70%) agreed that there are potential benefits of improving their balance and strength, along with the prevention of falls through this exergame intervention.

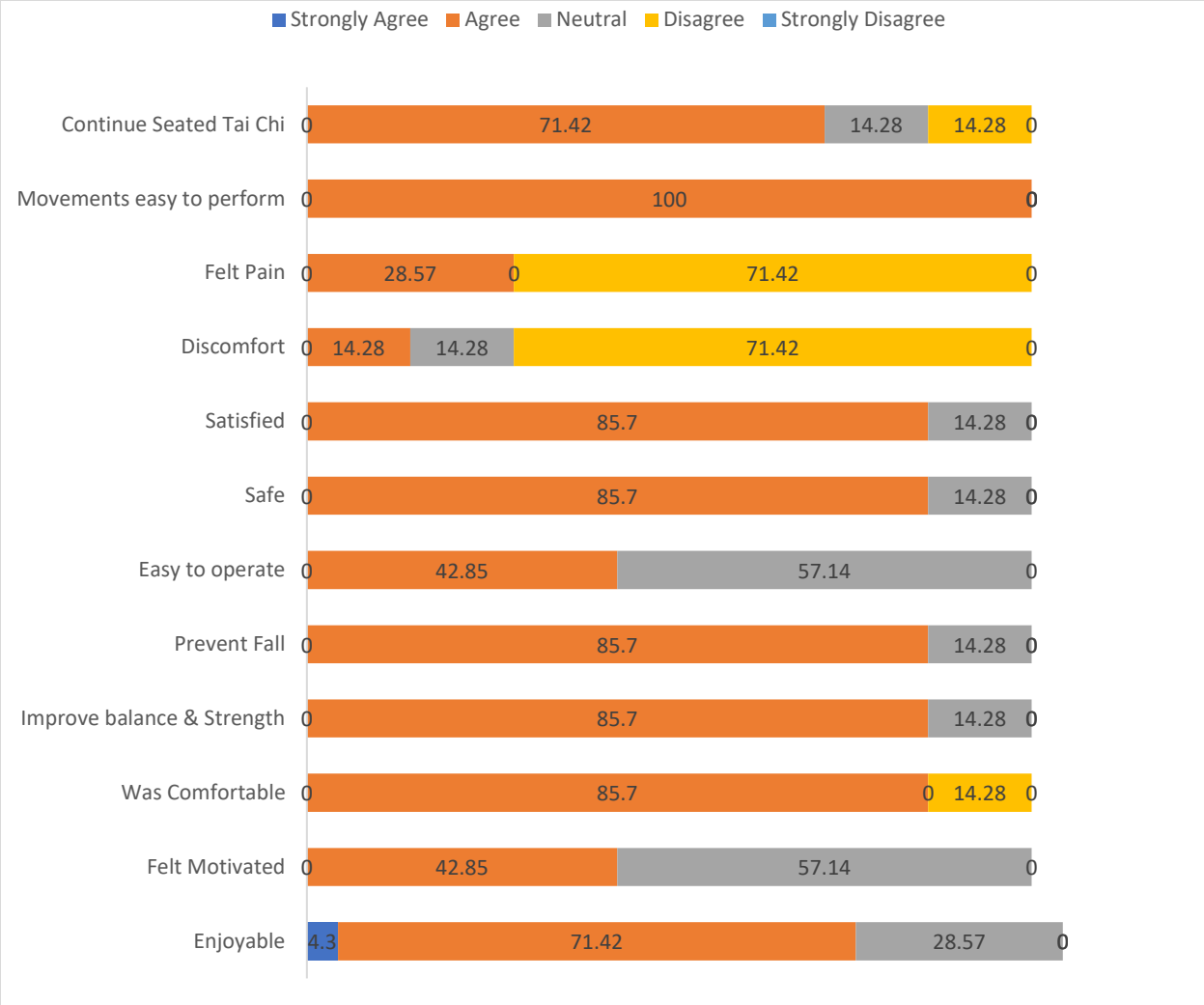
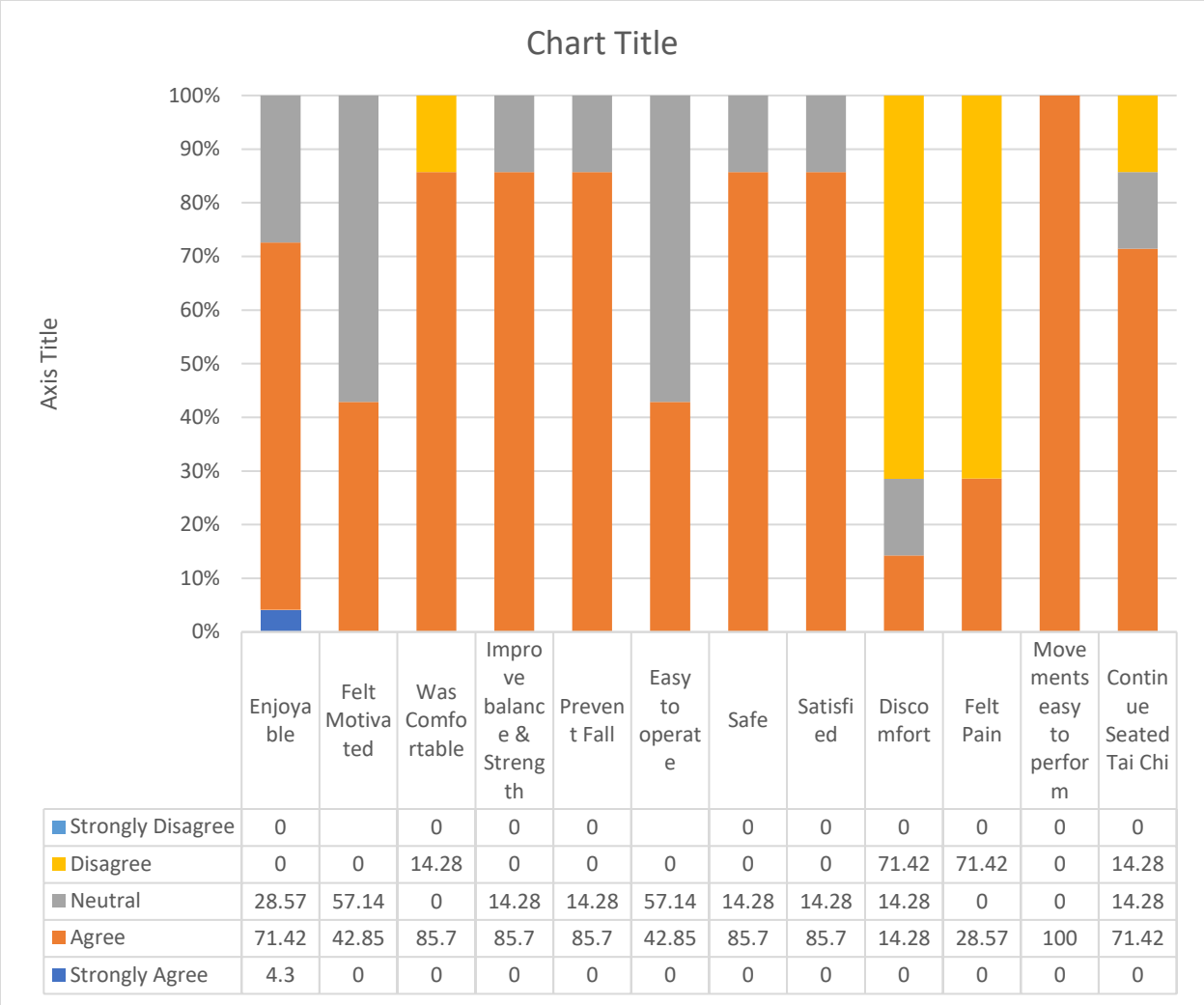


Figure 4.1: Post-Exergame Survey Findings



	Enjoyable	Felt Motivated	Was Comfortable	Improve balance & Strength	Prevent Fall	Easy to operate	Safe	Satisfied	Discomfort	Felt Pain	Movements easy to perform	Continue Seated Tai Chi
Strongly Disagree	0		0	0	0		0	0	0	0	0	0
Disagree	0	0	14.28	0	0	0	0	0	71.42	71.42	0	14.28
Neutral	28.57	57.14	0	14.28	14.28	57.14	14.28	14.28	14.28	0	0	14.28
Agree	71.42	42.85	85.7	85.7	85.7	42.85	85.7	85.7	14.28	28.57	100	71.42
Strongly Agree	4.3	0	0	0	0	0	0	0	0	0	0	0

Future potentials for use:

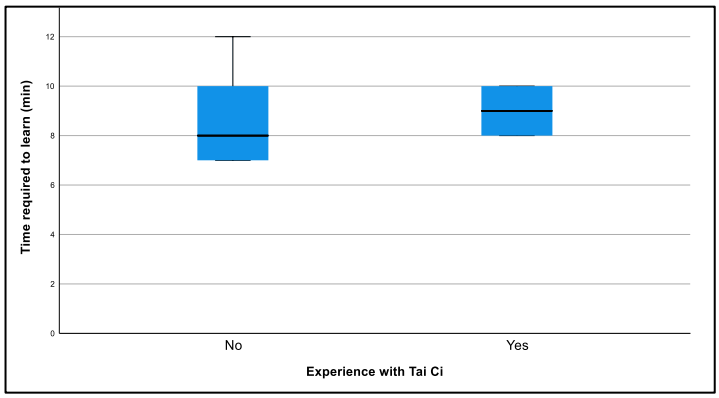
Motivation and future continuation to practice STC was dependent on how much they enjoyed this exergame. As shown in figure 4.1, majority of the participants (71.42%) agreed that this STC is enjoyable and agreed to continue in future. Approximately half of the participants (43%) agreed that they are motivated for future practice, whereas 57% remained neutral. Overall, these findings suggest that further exploration is required to improve the usability of technology for older adults which is discussed elaborately in the next section.

Task assessment result:

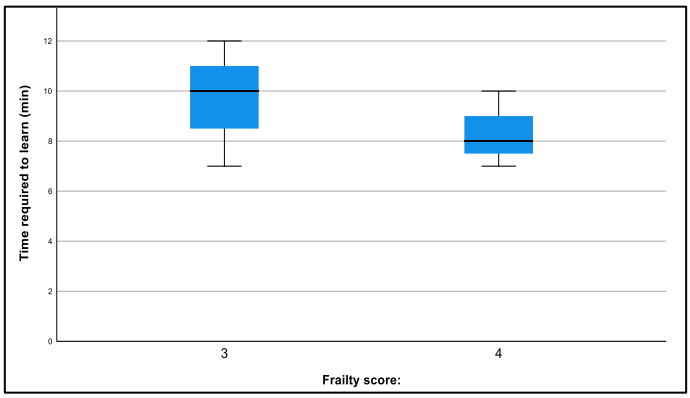
The task assessment aimed to examine whether the STC is easy to adopt by the participants, and were assessed in relation to levels of comfort, learning time of technology use, any adverse events, and performance scores. Here, Table 4.2 illustrates the mean duration required to complete each session, the mean performance scores of each session, the mean length of the break between the sessions, and the mean frailty and MMSE scores of the participants.

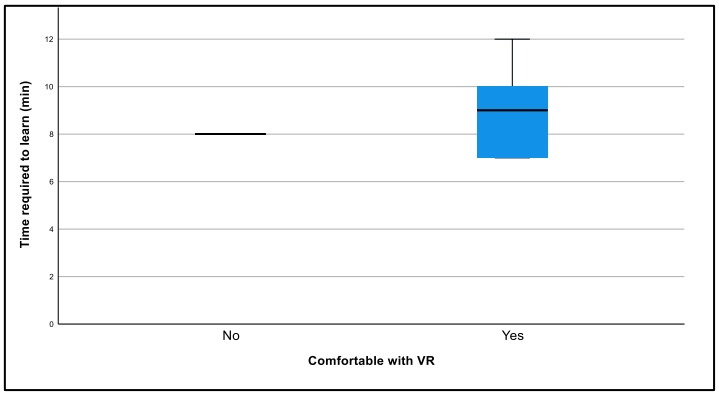
Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Session 1 Duration (min)	7	8	10	8.57	0.976
Session 2 Duration (min)	7	5	8	6.57	0.976
Session 1 Performance score (%)	7	6	32	17.29	9.690
Session 2 Performance score (%)	7	28	75	52.43	18.256
Duration of completion (min)	7	15	20	17.14	1.676
Duration of breaks between sessions (min)	7	0	5	2.00	1.732
Time required to learn (min)	7	7	12	8.86	1.864
Frailty score:	7	3	4	3.57	.535
MMSE score:	7	19	28	22.43	3.867

Table 4.2: Descriptive Statistics of the Participants



(a)





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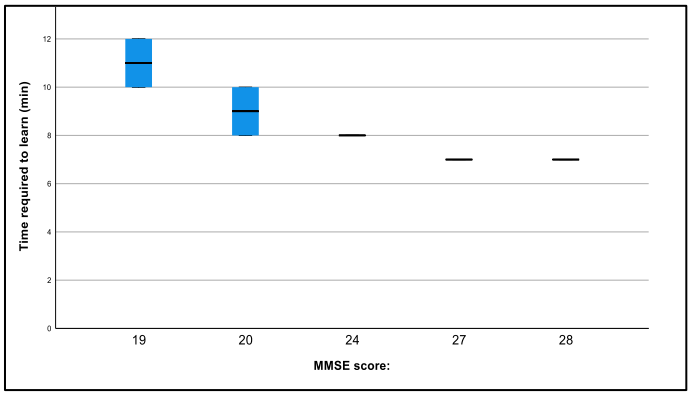


(b)

(d)

Figure 4.2: Data distribution : (a) Experience with Tai Chi (b) Frailty score (c) Comfortable with VR, and (d) MMSE score in relation to learning time

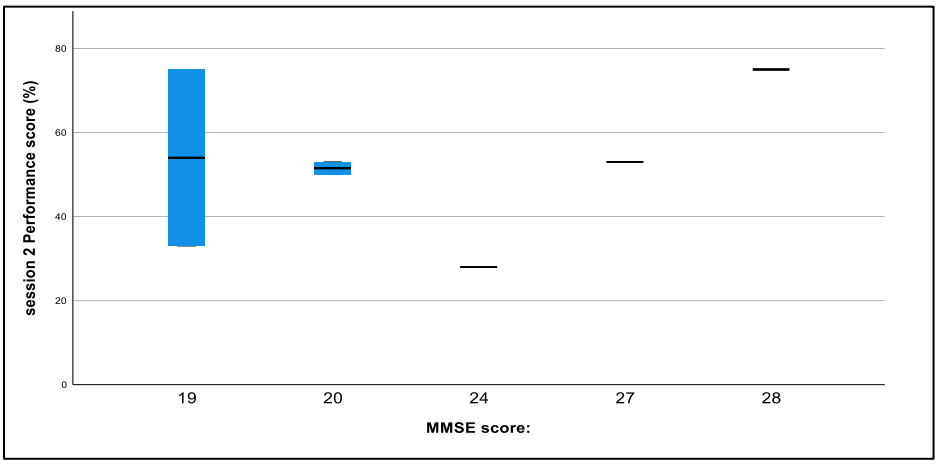


Figure 4.3: Data distribution: MMSE score in relation to Session 2 performance score.

The average duration for administering the first session was found to be 8.57 minutes with a standard deviation (SD) of 0.976, whereas the average duration for the second session was 6.57 minutes with the same SD. The average break time between the two doses was approximately 2 minutes (SD 1.732).

The Your Shape Fitness software tracked and provided scores for upper body movements only as participants were in seated position. On average, participants spent 17.14 minutes (SD 1.676) completing the exercise task. Additionally, participants took an average of 8.90 minutes to learn how to perform the STC exergame exercise, including understanding how to initiate the exercise through simple hand gestures, following the virtual instructor, and when and where to stop the exercise. Figure 4.2 displays the data distribution among training duration, frailty score, comfort level with VR, and the participants' MMSE score. The results indicate that participants with a lower MMSE score required more training

time compared to those with a higher MMSE score. Figure 4.3 depicts a larger interquartile range, implying that participants with a lower MMSE score exhibit more significant variations in their performance during session 2, with both lower and higher levels of performance. These findings suggest that MMSE scores can impact training duration and performance, which may have implications for designing interventions for individuals with cognitive impairment.

In Table 4.2, the average performance score for the first session was 17.29% (SD 9.690), while it was 52.43% (SD 18.256) for the second session. Figure 4.4 depicts the changes in performance scores between the two sessions, with the maximum improvement being 54% and the minimum being 8%, and the average improvement being 37%. Table 4.4 showed the same changes at the individual level with an average improvement of 37%. Participants 2 and 3 had the least increase in the performance. The contributing factor could be lower MMSE score or facing adverse event. To ascertain the significance of these changes, a Wilcoxon Signed Ranked Test was conducted, with the results presented in Table 4.3, which reveal a significant improvement in performance score in the second session compared to the first (Standard Error 5.91, $P < 0.05$). These improvements in performance scores demonstrate the adaptability of the exergame. Importantly, no participant withdrew from the exercise session.

Hypothesis Test Summary		
Null Hypothesis	Test	Sig.[a,b]

The median of differences between session 1 Performance score (%) and session 2 Performance score (%) equals 0.	Related-Samples Wilcoxon Signed Rank Test	0.018
Decision		
Reject the null hypothesis.		

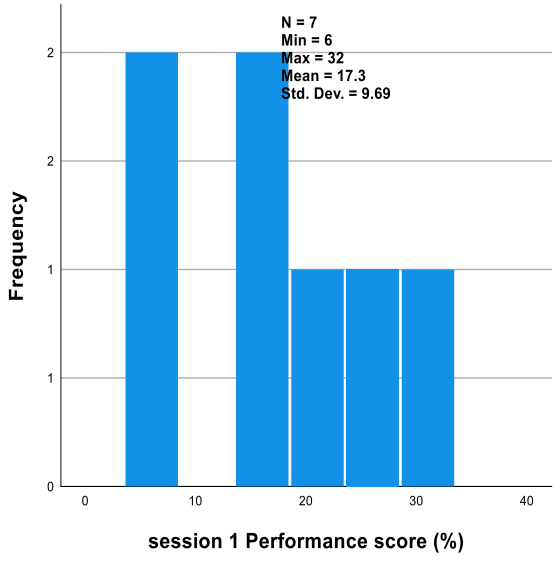
a. The significance level is .050.

b. Asymptotic significance is displayed.

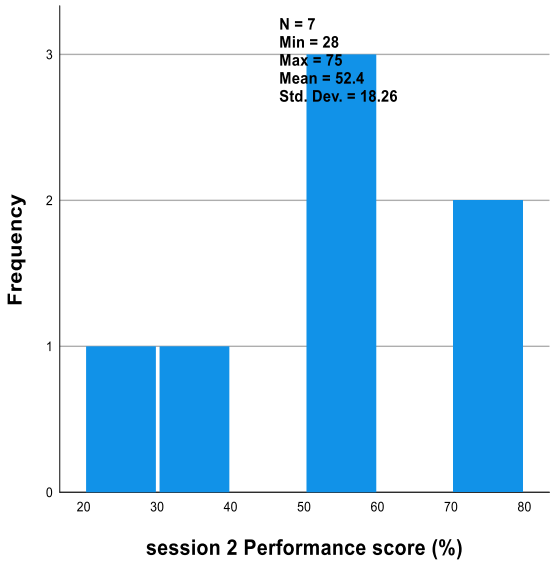
Related-Samples Wilcoxon Signed Rank Test Summary

Total N	7
Test Statistic	28.000
Standard Error	5.916
Standardized Test Statistic	2.366
Asymptotic Sig. (2-sided test)	0.018

Table 4.3: Wilcoxon Signed Ranked Test result.



(a)



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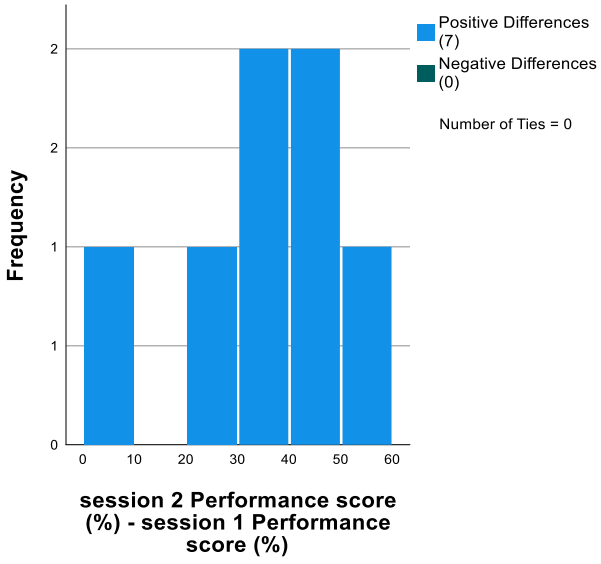

(c)

Figure 4.4: Performance score comparison between two sessions

Participant	Difference between performance score
P1	54% increased
P2	8% increased
P3	21% increased
P4	47% increased
P5	36% increased
P6	39% increased
P7	43% increased

Table 4.4: Difference of performance score between 2 doses of individual participants

Effect sizes for changes from session 1 to 2:

To evaluate the effect size for changes from session one to session two we calculated the effect size by taking the difference in means between the two sessions divided by the standard deviation of the session one.

Effect Size = (Mean of session one performance - Mean of session two performance) / SD of session two performance score

= (52.4 – 17.3)/18.26

= 1.92, Cohen (1988)

Qualitative thematic findings:

Regarding the feasibility, acceptability, and usefulness of the STC exergame, a total of five overarching themes were revealed. The participants shared their thoughts and experience about the STC exergame and offered some suggestions for future practice.

The themes were interpreted and generated within the context of participating in STC exergame and based on the rankings of the closed survey questions. The thematic tree below provides a priority based order list of the qualitative findings (Figure 4.5)

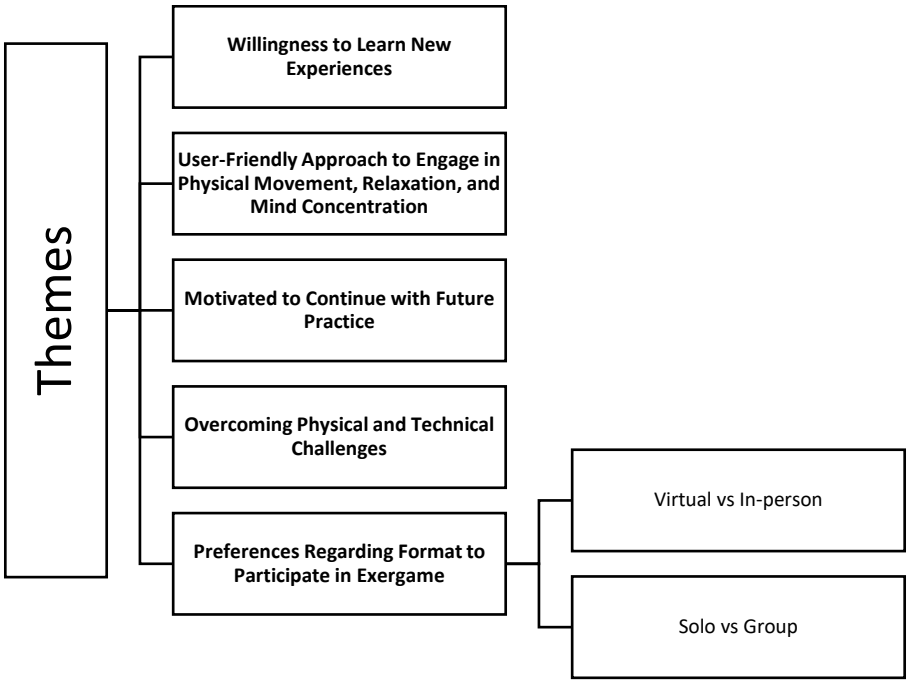

Figure 4.5: Thematic tree

Willingness to Learn New Experiences

Participant responses were nearly unanimous about STC being a new experience for them. STC and the VR exergame is a new experience for the majority of participants, which is similar to their survey responses about having minimal previous experiences with TC and VR. Descriptions centered around the importance of practicing more and honing their abilities to improve the use of seated TC were embedded throughout the responses of all the participants. Despite the sitting TC exergame presents a novel

experience comparing to the traditional exercise, the participants expressed the desire to learn new things.

Participants highlighted this during the interview-

“hmm. . . Something new for me” [P1]

“Oh, yeah, I can learn this…” “Well... I want to practice. This is new..” [P4]

The participants expressed a strong desire for practicing seated Tai Chi to further evaluate its potential benefits.

“..Everything can help from the beginning we don’t realize, but after a very long while we can get off. I remember I saw it, I was yeah, that’s the thing. And click to your brain. I experienced this in my life and now it’s clicking and it’s helping me. Yeah, I was getting a few times in my life situations like that. It happens to me before and I felt not like doing certain things first time just as I was doing repeatedly many times in my life..” [P5]

“I don’t know. . . I don’t know how much I would get out of this. This is new to me…” [P7]

User-Friendly Approach to Engage in Physical Movement, Relaxation, and Mind Concentration

Exercise can be relaxing, and TC is a form of relaxation exercise. The participants expressed their interest in and enjoyment of the STC exergame due to the opportunity to practice physical movement and mental concentration. participants echoed that-

“Yes it is quite easy. . I certainly would try it after. Why haven’t they done it before?” [P2]

“....Yes, for sure.It’s relaxing. ... I like it so far..” [P2]

The movements of the TC exergame was accepted as easy to follow (100%) by the participants. which is catered to their needs, and they wanted to practice more. Some quotes from the participants are-

> *"..Oh yeah. I need more practice…" [P1]*

> *"I like exercise like this, moving your arm and lifting and doing going this way and making exercise in different ways. It's a little easier for me but then it is the slow motion movement. It feels like your arms are too heavy.." [P3]*

Slow movements and participating with full concentration is key components of TC exercises., which in result is a positive factor for improvement of balance and concentration. Participant identified the need of these two components during their exercise session and realized this will help to improve their balance and strength and a result will potentially help in the reduction of falls (85.7%).

> *"It is good. I like this hand movements…it is relaxing…" [P4]*

> *"Yeah, for sure I will try. It's very good. If it helps us recover and keep us feeling that we haven't lost all our balance then for sure, definitely I will try." [P2]*

> *"Yes. You have to focus a little bit more concentration.. it needs concentration." [P5]*

> *"it might help me to improve my balance.." [P7]*

> *"I think it's pretty good. The stretching is what I like, the stretching part of it….The way they show it is easy to follow.. definitely it will help…" [P6]*

Motivated to Continue with Future Practice

It is very important to motivate these population to try something new and make them interested in future practice. While participating in the one-time exercise session participants felt motivated (42.85% agree, 57.15% neutral) and wanted to continue in future practice (71.42%). Participants expressed their interest to continue this exergame with future practice. The participants stated that-

> *"Oh yeah. I need more practice…" [P1]*
>
> *"Sure, I will try. Why not?" [P1]*
>
> *"Yeah, for sure. Yeah, it's very good. If it helps us recover and keep us feeling that we haven't lost all our balance then for sure. Definitely." [P2]*

In particular, participants showed interest to continue this exergame with their families. One participant was excited to use this with his grandson-

> *"Oh, that's good. And I know my grandson will do this with me." [P4]*

Participants were concerned about the situation of pandemic and found this exergame a good alternative to traditional TC, but it may have been helpful if adequate time and practice was provided. Their quotes are-

> *"..if It help you in current situation and time.. then yes it is helpful. But to be fascinated by something or someone, you need a little bit of time, more time just to know it better. …. I will gladly try this game. [P5]*

> *"Maybe with time. . . . It wasn't long enough. After a few practices, I can tell more about it, right?" [P5]*

> *"okay, get it. I'd like to see more about it, yeah. I'd say 60-65% (chances of use in future) "[P6]*

Overcoming Physical and Technical Challenges:

The people with frailty requires to spend more time to gain familiarity with the new technology and this VR exergame is no different. The Xbox Kinect requires a certain setup, and the participants need to adhere to the instruction provided on the screen.

There were a few points highlighted when asked about likes and dislikes of the TC exergame.

The technical knowledge to setup the Xbox Kinect was discussed by the participants as a barrier to use VR exergame. Participants expressed their need for assistance to set up the exergame on the screen.

> *"umm. . . it is.. but the screen is not large enough. . . And if we have somebody. . . if you could have somebody in front of it for instruction.. it will be easy." [P2]*

Participants shared their challenges to continue due to unfamiliarity with the technology.

> *"I'm not going to do it. . I'm not even savvy at putting things on the TV or anything Never learned this. My husband did everything." [P7]*

> *"I don't know, because it seems like it goes in very slow motion and that is heavier on my arm. I feel uncomfortable lifting my arm slowly up like this. It just feels like my arms are too heavy." [P3]*

> *"..it seems like lots of work. If someone sets this up for me. Then I can do it. I probably wouldn't bother Mike (husband). …. Because I don't want to learn something new. I don't want a commitment. . . Another commitment." [P7]*

Preferences Regarding Format to Participate in Exergame:

Two sub-themes were identified regarding the preferences to participate in exergame exercises: 1) Solo vs. Group Setting and 2) VR vs. In-person Format.

Solo vs. Group Setting

The participants have provided their perspectives on performing VR exercises in individual or group settings. The reasoning varies from person to person, from engaging in an individualized way of learning to being able to learn with others in a group setting.

> *"Oh alone... I am slow in learning..." [P1]*
>
> *"I suppose it'd be probably in a studio with people doing it." [P2]*
>
> *"I'd rather do it alone. because my time is crazy. Because if you do it in a group exercise, you have to be strict with time." [P6]*

Virtual vs. In-person Format

Participants showed interest in the STC exergame. One participant preferred the VR format over other physical activities led by an in-person instructor:

> *"I think it's more convenient. . . The virtual one.. this gives you instructions to follow. So that means you're doing what you should do, not skipping anything."[P6]*

All participants indicated that they have previously been involved in different instructor-led, in-person exercises. and they enjoyed the outdoor exercise experience rather than exercising in an indoor setting. Despite having an interest in this VR exergame, they

were hesitant to adopt new technology or to learn a new form of exercise in their already established daily routine:

> *“I would say I prefer in person activity... it is too much indoors. I do not like too much indoors....., but I’m not opposed to this. But I prefer outdoors. Okay. Or in a large studio, as you do in your home. It’s only a small room.” [P2]*
>
> *“I don’t think so. I think I’m going to stick to the pool and the commitment. I can’t make too many commitments because then I get all piled up..” [P7]*
>
> *“I would prefer not to. I prefer the other exercise we did. And I do physio. I do walk and different lifting sideways up and down like this. It works better for me.”[P3]*
>
> *“Possibly would like to get more involved with running and jumping and stuff like that”[P4]*

Chapter 5: Discussion

This pilot study aimed to assess the feasibility, usability, and acceptability of a STC exergame among frail older adult with mild dementia or PD. The results from two sessions of STC exercise, along with the survey questionnaires and one to one interview revealed the following potential of STC exergame for patients with PD and/or with dementia:

1. **User-friendly alternative to traditional exercise,**
2. **Improving exercise adherence through engaging in new experiences, and**
3. **Potential to increase physical stimulation, induce relaxation, and improve concentration.**
4. **Novel method to track adherence and improvement.**

The results of this study suggested that the STC exergame was well received by the participants. They found the STC exergame user-friendly and expressed intention to use the system. Results from this study showed the potential of the exergame to engage the participants in increased physical stimulation, relaxation, and mind concentration. The participants were also motivated by STC exergame as it offers new engaging experiences which will help to improve exercise adherence. This study identified potential barriers and suggested future recommendations to improve the STC experience.

1. **User-friendly alternative to traditional exercise:**

One of the primary findings of this study was to assess the usability of the STC exergame with patients with mild dementia or PD. There exist different types of VR based gaming consoles in the literature to promote the well-being of PD and/or dementia (Klempel et al., 2021, Lee et al., 2018, Hsieh et al., 2018, Rose et al., 2021). Among them, commercial

gaming consoles, such as the Nintendo Wii, Microsoft Kinect Xbox, and the PlayStation, Oculus Quest 2 are widely used (Johansen et al., 2020). However, limitations arise from both hardware and software level when frail participants with cognitive impairment put these consoles in use. For example, frail older adults with dementia found the Wii Sports screen too complicated to enable quick understanding, challenging to manipulate the Wiimote buttons (input device), and the posture requirements (standing) inappropriate (Hsieh et al., 2018). Head-mounted displays (HMD) are also frequently used as visual devices. However, Rose et al. (2021) was unable to rate the observations of effect specifically in relation to eyes due to headset covering the participants' eyes. Controller-based devices, such as PlayStation requires the user to use hand controller to interact with their virtual environment. Unfortunately, hand controllers can be complicated for participants with cognitive impairment or dementia (Tuena et al, 2020). On the other hand, controller-free interfaces or haptic gloves (wearable device which allow users to experience realistic touch and interactions) were recommended by several studies as they are more intuitive to use (Vines et al, 2015; Chang et al, 2020). The hands-free, easy to navigate mechanism of Kinect mitigates the limitations as the participants were not required to use HMD or hand-controller. There are several studies which support the "user-friendly" and positive findings of patients with PD and/or mild dementia using Xbox Kinect (Kayama et al, 2014; Sexton & Taylor et al, 2019).

A VR-based exergame environment is dynamic, and this, coupled with high degree of immersion will create an illusion of self-motion. (Seppänen et al., 2020). However, because the participant is often stationary, this can cause sensory conflict leading to few side effects such as nausea, oculomotor, and disorientation symptoms. Studies have

shown that an HMD causes higher symptoms of nausea than the desktop screen and higher oculomotor and disorientation symptoms than VR theatre viewing (Sharples et al, 2018) The participants of our study did not experience the above-mentioned side effects since no HMD or controller were required. But we must keep in mind that these side effects are associated with user performance, safety, immersion level and acceptance (Stanney et al, 2016).

Previous studies reported no adverse events related to the STC intervention (Gao et al., 2012; Hsu et al., 2016a, 2016b; Lee et al., 2015; Tsang et al., 2015; Qi et al., 2018). Similarly, our intervention was found to be safe with no serious intervention-related adverse events reported.

We kept track of the user score of the first and second dose of the exercise session. As the session progressed following the avatar's instructions, the correct movement became more manageable and intuitive for the participants. Manera et al (2015) reported similar improvement in the game activities where they found significant positive change for the second dosage as a result of training with the patients with mild cognitive impairment. Perceived user satisfaction based on non-verbal emotions and behaviors (positive facial expression, such as smiling, nodding head) was observed after participants experienced improvement in the exergame performance score.

2. **Improving exercise adherence through engaging in new experiences:**

To improve the challenges of adopting the interventions, few strategies could have been implemented. Training materials, spot checking the instructions (Hsu et al., 2016b), and adding supplementary health assessments (Cheung et al., 2007) were found useful to

increase adherence and reduce dropout. In terms of training materials, Vidoni et al. (2016) used exercise booklet with daily goals, Rosenberg et al. (2012) used printed materials including a map with 3 walking routes and handouts with step counts to local destinations. Cheung et al. (2007) evaluated the cardiovascular function, pulmonary function, and shoulder range of motion as three additional health metrics. This decision was made in part because of findings from earlier studies that suggested practising TC could lead to improvements in these metrics. (Hong et al., 2000; Li et al., 2001). Home practice in complementary to regular intervention regimen and exercise logbooks (Tsang et al., 2015) were found to be beneficial in promoting exercise adherence.

Studies showed that older participants had trouble appreciating the benefits of novel health-related technologies (Clemensen et al., 2013; Huh, Le, Reeder, Thompson, & Demiris, 2013). Heart & Kalderon (2013) pointed out that the older individuals must have a specific advantage to utilize an exergame in order for them to adopt it in their daily life. Similar to a previous study, the participants of our study were willing to further engage in increased physical activity programme with the VR-based exergame using the Kinect for Xbox 360 since it provides participants the opportunity to move around safely while giving them the opportunity to reduce sedentary behaviour (Leutwyler et al, 2015).

There have been reports of limited adherence to the traditional exercise program even though it has beneficial impacts on cognitive and physical function in PWD and PD. Older age, poorer cognitive function, increased symptoms of depression, and greater disability are the main causes of exercise non-adherence (Beishuizen et al, 2017, Rolland et al, 2007, Prohaska and Peters, 2007). Several studies have encountered these issues especially when the game is intended to be played independently (Skjæret, Nawaz,

Morat, Schoene, Helbostad, & Vereijken, 2016). To overcome these limitations, our study tried to focus on tracking progress through visualizations to encourage increased motivation and engagement, which in turn could improve participants' adherence to the daily exercise regimen.

Education is essential to ensure that participants can read and comprehend the significance of the in-game score (Grönvall & Verdezoto, 2013b). In our study, participants were at least high school educated who can read and follow instructions. Li, Dey, and Forlizzi's (2011) showed that participants were interested and motivated by the in-game data that shows the game status, score related to the participating player's goal. We also observed that participants could notice the real-time feedback mechanisms employed during our STC exergame sessions, which encouraged them to participate in further practicing of exercises. Our STC exergame highlighted a successful motion by making a sound and displaying a green gesture as positive feedback to encourage further participation. These scoring elements are placed at the right lower corner of the game so that the players could focus on following the avatar's movement and not get distracted by these secondary visual elements.

Similar to our findings, previous research has found that a proportion of older people prefer to exercise in their own homes, (Yardley et al, 2007; Brawley et al, 2003) as they find it is more convenient and reduces some of the perceived barriers to exercise, including adverse weather conditions (Newson and Kems, 2007 , Cohen-Mansfi eld et al., 2003) lack of transport, (Tudor-Lock et al., 2003, Whitehead et al., 2003) and feelings of intimidation to attend fitness facilities and group exercise settings (Tuena et al., 2020). Valenzuela et al. (2018) found 100% adherence rate for an exergame even in

unsupervised condition. Our study showed that the Xbox console with a Kinect sensor console can be set up in places where a working internet connection and screen with visual input (HDMI) is available.

Our study revealed similar findings from the literature which examined ways to increase exercise adherence through the use of technology. It was found that older people desire explicit on-screen instructions, tailored exercise direction and progression, a variety of physical and cognitive exercises, and the ability to exercise at home in their own time (Sherrington et al., 2008).

Moreover, our STC game mimics an outdoor virtual environment which could complement the preference of those participants who preferred to engage in outdoor physical activities, but find it difficult to engage due to perceptual, motor, and cognitive changes that come with ageing, Parkinson's or dementia.

3. **Potential to increase physical stimulation, induce relaxation, and improve concentration:**

One of the findings of this study was the participant's perception of the benefit of STC exergame to maintain their health and live independently. The survey and interview revealed that the participants agreed using an avatar as a coach or a companion and believed that the STC exergame would potentially be beneficial to improve balance, strength, and mind concentration.

Previous research found that simple traditional Tai Chi exercise program (six forms of TC jointly developed by a TC master and a physician who practiced TC) is effective to significantly improve the balance and risks of falls among older adults with dementia (Lin

et al. (2019). However, patients with mild dementia or PD suffer from cognitive impairment as well as balance disorders and therefore it is critical to implement different forms of exercise that are tailored to their individual needs and safety considerations. Hence, a seated position is the safest and promising positions for performing exercise for those whom the standing position is a challenge (Close et al., 2014). Exercises performed while sitting have beneficial physical and psychological effects on those who are unable to exercise while standing (Sexton and Tylor, 2019)

Recent studies have shown that seated exercise benefits several aspects of physical functions such as balance, gait speed, grip strength and others. Seated exercises are recommended to promote as simple and easily implemented activities to improve strength and offset the adverse effects of sedentarily lifestyle of frail older people (Klempel et al, 2021). Gao et al. (2014) found TC not only benefits physical functioning such as muscle strength, coordination, cardio protective effects, but also social functions. A pilot study by Ken Y. T. Lee et al (2014) showed that three months STC training can improve sitting balance and accuracy in the finger pointing task in the older adults. Lee, Jones, Hui-Chan, & Tsang, (2011) investigated the energy expenditure to confirm that STC is a low intensity exercise which targets to improve to the balance control of frail older people who cannot perform traditional TC. STC also promotes self-efficacy in exercise (Hsu et al, 2016), and improves quality of life if perform in a group setting and enhance social interactions with others (Qi et al, 2018; Chen-YuanHsu et al, 2016).

Participants of this study believed that STC could potentially improve the muscles' strength, which confirms the findings from previous research where STC was believed to have benefits in increasing the strength of muscles in the shoulder region and increasing

joint flexibility (Siu et al., 2007). When performing TC while seated, the hands and arms are primarily moved from the shoulders and waist, which act as the driving forces for the hands and arms. The hands, arms, and shoulders must alternately move from front to back, up, and down, and left to right. The arms and hands are typically kept in suspended positions during these coordinated and sustained slow movements. These positions and motions, especially for people who don't exercise, may aid in building shoulder muscular strength. The range of external shoulder rotation and shoulder extension movements should improve as the shoulder muscles get stronger (Siu et al, 2007).

Extremity function is a broad term that covers a variety of activities, such as joint movement in people with restricted physical mobility (O'Sullivan et al., 2019), sensation (Zhao et al., 2021), and motor functioning. Previous research examined the effects of STC on extremities function found a substantial positive effect using the Fugl-Meyer Assessment (Gao et al., 2012).

Chen et al. (2007) revealed that STC significantly lessens weariness as determined by the Fatigue Index. Among our research participants, they reported short-term relaxation after performing STC exergame. Based on the Modified Barthel Index, Gao et al. (2012) found a substantial improvement in daily living activities, which refers to independent care for oneself, such as eating, bathing, and movement (Edemekong et al., 2020), in the STC group. The amount of eye-hand synchronization required for pointing precision was substantially higher in related studies (Lee et al., 2015; Lu et al., 2009). None of the included studies reported participants' perspectives related to their experiences with the STC intervention. To our knowledge, this study is the first time where we focused on exploring particiants’ perceived experience related to the use of TC exergaming.

According to prior research (Kasper et al., 2017) exergaming satisfies the criteria for a successful treatment to improve physical and cognitive stimulation since it is highly customised, interactive, and focused on the achievement of shared goals. Exergame enhances the movement and cognitive abilities of people with dementia. Additionally, "modest" to "moderate" effect sizes were identified by some research for the outcomes related to cognitive performance associated with exergaming (Padala et al., 2012 Ben-Sadoun et al., 2016).

Kinect based TC have shown improvement in depression along with physical activity level for PD and /or dementia (Neubauer et al, 2017). According to Manera et al, 2015, participants with dementia or mild cognitive impairment expressed high levels of user satisfaction and experienced no weariness or fear with VR-based games. Lower apathy has been identified before using the VR-based games, and participants reported higher levels of happiness after using the VR-based games (Moyle et al., 2018). This aligns with our study where user satisfaction, short-term relaxation and enjoyment have been reported after the exergame intervention with an intention to continue with future practice.

Patients typically need to visit an outpatient clinic or rehabilitation facility to follow the physical therapists' instructions when performing TC exercises. However, this might be troublesome for a patient who requires time and money for transportation to these facilities. Additionally, the quality of individualized therapy may suffer if a physical therapist is required to care for multiple patients simultaneously. Hiring a home therapist is one solution, but it is not financially feasible (Chien-Hsing et al., 2013). Similar to our study approach, Lee et al. (2018) conducted a study on virtual reality-based TC (VRTC) for patients at home using a Kinect. Their results showed that VRTC increases their

participants' motivation for physical exercises, as well as improving their exercise performance during the intervention phase.

4. **Novel method to track adherence and improvement.**

All the studies that we have found have periodically assessed the participants' performance and reported the result (Gao et al. (2014); Lee et al. (2014), Hsu et al. (2015), Lu et al. (2009) and Lin et al. (2019). In our Kinect-based VRTC, the user was able to create a profile, and every time they use it, their performance score can be stored in their profile along with the real-time feedback from the games, as mentioned earlier. The correctness of the participants' gestures was primarily visual; usually, the TC master observes the participants' movements and assesses them. Kinect-based motion tracking uses sensor data from real-time limb movements and calculates the appropriate calculation to match the gesture the avatar provides. A score is provided when the gesture is made correctly. Moreover, this novel tracking, feedback, and performance measure can be done without wearing any device and can be easily setup.

Challenges related to Seated Tai Chi Exergame:

The limited technical knowledge of the participants in the utilization of the exergame was a major challenge in our study. The participants were from a generation where smartphones, console games were not invented. This potentially creates a barrier for them to become easily accustomed to the use of STC exergame. Nguyen et al (2018) pointed out that one of the barriers to implement VR exergame is the perceived ease of

use by the participants, which is highly dependent upon their familiarity with the use of technology.

When setting up the Xbox 360 Kinect, it is crucial to consider the available space, the function of the rooms, the use of current technology (i.e. television), and individual preferences (Axelrod et al., 2009). The participants' preference regarding the format of the exergame varied based on their personal choice. While half of the participant wanted to practice solo due to their concern of being distracted by others or being a slow learner, which can be linked to their fear and concern with learning a new technology. On the other hand, another group of participants preferred to work in a group in order to feel motivated.

The participants could potentially experience the long-term benefits of seated virtual-reality TC for an extended period of time, which is beyond the evaluation of our current pilot study. According to previous TC studies, practicing TC can help older adults with their balance control, not just after longer-term practice (more than a year) (Hong et al., 2000; Tse & Bailey, 1992) but also after medium-term practice (six months) (Li et al., 2005; Wolfson et al., 1996) and short-term practice (8–10 weeks) (Schaller, 1996; Tsang & Hui-Chan, 2004). On the other hand, the benefits of STC intervention spanned anywhere between four (Gao et al., 2012) and 26 weeks (Hsu et al., 2016a, 2016b). These studies typically used a length of 12 weeks and a weekly dosage of 120 or 180 minutes. The dosage ranged from 60 minutes (Li et al., 2012) to 300 minutes per week (Qi et al., 2018).

Chapter 6: Implications and Conclusion

Study Limitations:

Since the participants only took part in the programme for two sessions, there are some limitations associated with a pilot feasibility study. If additional exercise sessions are implemented, a potential effect on in-game scores could have been detected.

Additionally, we conducted the exercise session with the types of TC movements available on the exergame software which could potentially limit the impact of engaging in the full spectrum of TC exercise. In the future, we intend to include other TC movements to allow the participants to experience the complete exercise regimen. Despite these limitations, our study provides important baseline data regarding the feasibility and usability of using virtual reality-based exergame to improve physical activity and health outcomes in people with Parkinson's disease and/or mild dementia.

The recruitment of participants was another challenge of this study. The recruitment was done when covid-19 restrictions had just begun to be lifted, and potential participants were still in the transition period to participate in pre-covid protocols. These make it more challenging to find more participants with PD or participants who have both conditions. We plan to include them in future work. The results of this study represent an essential "first step" in creating an innovative physical activity programme for frail older persons with PD and/or moderate dementia using virtual reality exergaming. Future research should evaluate the adoption of technology and the change in long-term behavioural patterns. It is recommended that future trials with larger samples size of other study

populations in diverse clinical settings (i.e., long-term care facilities) could increase the generalizability of the study results (Hsu et al., 2016b).

Future recommendations:

Implications for practice

Based on the study results, seated TC exergame, which incorporates a mind-body strategy, is useful for patients with limited physical mobility and can offer potential positive physiological and psychological outcomes. This study concluded that no adverse incidents has occurred which indicated the safety of the exercise regimen.

Despite the positive attitudes toward the value of using exergame, most of the participants did not feel comfortable setting up the technology. To overcome these challenges, technical support is needed to help increase user satisfaction and decrease levels of frustration. Providing supplementary training materials could help aid in minimising the performance flaws that we have observed during the pilot study. Increasing perceived ease of use could increase the system's usability, which could increase the initial and ongoing adoption of the system by our target populations.

More people are becoming aware of the advantages of incorporating holistic, non-pharmacological treatments (Romeyke & Stummer, 2015). Therefore, seated TC should be used in complementary with other traditional forms of therapies to improve the physical and cognitive outcomes of patients with PD and dementia (Tsang et al., 2015).

Additionally, seated virtual reality-based TC has the potential to help empower and motivate the participants to take charge of their own health and engage in increased physical activity (Choo et al., 2020). In countries or rural areas where there is a lack of resources for in-patient and outpatient rehabilitation, virtual reality-based exergame therapy can be beneficial to be implemented and utilized in the home and community settings (Bethge et al., 2014).

Implications for research

Future randomized controlled trials can be implemented to examine the effectiveness of Tai Chi exergame using valid experimental designs and bias reduction techniques. Different types of software for seated and standing TC exergame need to be explored in future studies to examine its impact on clinical outcomes. Future research on using TC exergame for people with cognitive and balance impairment transitioning from hospital to community settings with various health co-morbidities will be valuable. It is necessary to conduct additional research comparing the effects of various levels of doses, frequency, types, and styles of TC exergame. Monitoring of adverse event reporting, assessment of participant satisfaction, and long-term follow-up evaluation should be the important considerations for future studies.

Conclusion:

Seated TC exergame is easy to adopt, user friendly, safe technology and has the potential to improve physical fitness among patients with mild dementia and a promising alternative exercise platform for individual with PD. Proper training needs to be put in place to encourage long-term practice and maximize exercise adherence. This study appears to be the first pilot study to investigate the usability of Seated TC exergame on frail older adults with mild dementia or PD utilizing Kinect. These pilot results provide valuable lessons learned to pave the path for the implementation of future study involving larger sample size to examine the efficacy and effectiveness of TC exergame for older adults with neurological conditions and cognitive impairment.

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Appendix

APPENDIX A: RECRUITMENT FLYER

ARE YOU INTERESTED IN PARTICIPATING IN A NON-IMMERSIVE VIRTUAL REALITY-BASED EXERCISE PROGRAM?

PARTICIPANTS NEEDED

We want to explore with you the feasibility, acceptability, and usability of a non-immersive virtual reality-based seated Tai Chi exergame program (No need for standing or a VR headset) for older adults with Parkinson's disease and/or mild dementia with the intention of balance control and reducing the risk of falls.

We cordially invite you to participate in a research study that involves participating in an exercise program, along with a questionnaire and interview (about 60 minutes) to explore your experiences regarding seated TC exergame. **You will not be required to stand or wear any special equipment**.

YOU ARE ELIGIBLE IF YOU ARE:

- ✓ Older adults with mild dementia or Parkinson's Disease.
- ✓ Fifty-five years of age and older.
- ✓ Have a history of fall or near fall in the last year.
- ✓ Able to provide informed consent on your own.
- ✓ Can speak in English.

If you want to participate, please contact:

Farzana Rahman

Graduate Student

Faculty of Health Science

Ontario Tech University

Contact number/email: 403-929-5258, Farzana.rahman@ontariotechu.net

Appendix: B - Email Recruitment Script:" Exciting Exercise Program for Mild dementia or Parkinson's Disease"

Research Title: The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild dementia or Parkinson's Disease: A Pilot Study.

Hello,

My name is Farzana Rahman, and I am a graduate student at Ontario Tech University and am running a research study through Ontario Shores Centre for Mental Health Sciences.
You are invited to participate in a voluntary research study titled "***The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild dementia or Parkinson's Disease: A Pilot Study***," currently being conducted by Ontario Tech University, as you have seen the flyer or been identified by your physician.

Purpose and Process:

The primary purpose of this proposed research is to evaluate the feasibility, acceptability, usability, and experiences of using virtual reality-based seated Tai Chi exergame. The study will provide information about the feasibility of using Tai Chi exergame for the potential improvement of balance, reduction of the risk of falls, and improvement of frailty through non-immersive Tai Chi exergame where participants do not need to stand or wear any instruments.

You will be asked to provide information about yourself (e.g., age, gender,) and complete a brief demographics questionnaire before the start of the exercise. This short questionnaire will provide some information about you to help us better understand the research data. After the exercise program, you will answer a series of closed and open-ended questions regarding the feasibility and usability experiences of the exergame. The questions will take about 10-15 minutes to complete. Also, there will be a short interview (15-20 minutes) after the session to get in-depth knowledge about your perception regarding using the exergame. This interview will be audio recorded upon your consent for future data analysis.

The total expected duration of participation in this research is 60- 70 minutes.

Potential Benefits:

Several studies have shown the benefits of Tai chi for both the physical and mental aspects of people with PD and/or Dementia. But to the best of the author's knowledge, no research has been conducted to evaluate suitable movements specifically for the frail older adult with PD and/or dementia in a virtual environment. The outcome of this feasibility research will provide us with a collection of potential useful Tai Chi movements that you will be able to practice despite your physical limitation.

This study will provide you with the opportunity to engage and interact in a safe, easy to perform, affordable VR-based exercise program.

This research will provide you with the opportunity to engage in an exercise program by interacting with VR. As this exergame offers real-time feedback, you will receive an immediate feedback score on your movements. At the end of the session, you will receive their overall scores. This score will help you to gauge the condition of your upper body posture. A higher score will indicate better movement performance levels and will be effective in better fitness levels, while a lower score will suggest otherwise. Thus, it may potentially improve your balance and strength, which may, in turn, have potential benefits to decrease your risks for falls and frailty levels in the long term.

As a thank you for participating, you will receive a $20 gift card from Tim Hortons.

Attached is a consent form for further details for you to review. If you are interested in participating, please contact:

Farzana Rahman

Graduate Student

Faculty of Health Sciences

Ontario Tech University

Contact number/email: 403-929-5258, Farzana.rahman@ontariotechu.net

Appendix C: Verbal Recruitment Script

Hello,

My name is Farzana Rahman, and I am a graduate student at Ontario Tech University. I am currently doing a research study titled "The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild dementia or Parkinson's Disease: A Pilot Study." I have called you to invite you to voluntarily participate in this study as you have been identified by your physician, and you have shown interest in participating.

The primary purpose of this proposed research is to evaluate the feasibility, acceptability, usability, and experiences of using seated Tai Chi exergame. The study will provide information about the feasibility of using exergame for the potential reduction of the risk of falls and improvement of frailty through non-immersive Tai Chi exergame where participants do not need to stand or wear any instruments.

You will be asked to provide information about yourself through a brief demographic questionnaire before the start of the exercise. This short questionnaire will give some information about you to help us better understand the research data. After the exercise program, you will answer a series of closed and open-ended questions regarding the feasibility and usability experiences of the exergame. The questions will take about 10-15 minutes to complete. Also, there will be a short interview (15-20 minutes) after the session to get in-depth knowledge about your perception regarding using the exergame. This interview will be audio recorded upon your consent for future data analysis.

The total expected duration of participation in this research is 60- 70 minutes.

The outcome of this feasibility research will provide us with a collection of potential useful Tai Chi movements that you will be able to practice despite your physical limitation. This study will provide you with the opportunity to engage and interact in a safe, easy to perform, affordable VR-based exercise program during their time of participation. Your experience and descriptive thoughts about completing the exercise session will explicate

your perspectives regarding the acceptability of this exergame. As this exergame provides real-time feedback, you will receive an immediate feedback score of your movements. At the end of the session, you will receive your overall scores. This score will help you gauge the condition of your upper body posture. A higher score will indicate a better movement which will be adequate to have better fitness levels, while a lower score will suggest otherwise. Thus, it may potentially improve your balance and strength, which may, in turn, have potential benefits to decrease your the risks for falls and increased frailty levels in the long term.

I have sent a copy of the consent form that provided further details for you to have reviewed. If you would like to review the consent form with me now, I can go over it with you. If you are willing to participate, you can speak with me further now so that we can set up a time that works for you to go over the study details, or you can email or call me at a later date to schedule a meeting. My contact information is in the flyer that you provided.

APPENDIX D: STUDY INFORMATION AND INFORMED CONSENT FORM

Title of Research Study: The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild Dementia or Parkinson's Disease: A Pilot Study

Site Principal Investigator: Dr.Sarah Elmi, Ontario Shores Centre for Mental Health Sciences

Site Co-Investigators: Dr. Amer Burhan, Dr. Arany Shanmugalingam, Ontario Shores Centre for Mental Health Sciences

External Co-Investigator: Dr. Winnie Sun, Ontario Tech University

External Graduate Student Investigator: Farzana Rahman, Ontario Tech University

You are being invited to participate in a research study because you may:

- Be an older adult with mild dementia or Parkinson's Disease within the Geriatric Dementia Unit (GDU) or Geriatric Transitional Unit, or Outpatient Geriatric Mental Health clinic at Ontario Shores.
- Had a history of falls or near fall last year.
- Fifty-five years of age and older.
- Able to provide informed consent on your own.
- Can speak in English.

This consent form provides you with information to help you make an informed choice. Please read this document carefully and take the time to make your decision. You may find it helpful to discuss it with your friends and family. If you wish to participate, you will be asked to sign this form.

Taking part in this study is voluntary. You may choose not to take part, or if you choose to participate may leave the study at any time without giving a reason. Deciding not to take part or deciding to leave the study later will not result in any penalty or any loss of benefits to which you are entitled.

Background:

Balance impairment is a severe problem among patients with Parkinson's Disease (PD) and/or dementia. It is associated with restricted mobility and increased chances of falls, leading to functional decline, depressive symptoms, reduced quality of life, and contributing to frailty. Despite many promising pharmacological treatments to mitigate such conditions, researchers are showing more interest in the domain of non-pharmacological approaches. Tai Chi (TC) is one of the non-pharmacological approaches and an appropriate exercise for frail persons with mild dementia or PD . Several studies have shown that TC helps reduce the risk of falls by improving balance. Still, not all movements are suitable for everybody due to accessibility concerns, and low adherence is also reported. Conventional Tai Chi always demands time, space, human resources, and fees, which decrease the motivation and interest of the patients. Virtual reality (VR) can mitigate these issues because of its ease of use, safety considerations, indoor application, less supervision, and real-time feedback capability. Combining VR and video games or exercises is known as an exergame. Current studies suggested exergame as a viable and safe platform for a person with PD and dementia. No research has been conducted on the combination of VR and Tai Chi for balance in the context of frailty to improve falls in this population. For this purpose, a mixed-method pilot program will be conducted among participants with Mild dementia or PD to examine the feasibility, acceptability, and usability of the Seated Tai Chi exergame. The goal is to evaluate the feasibility of this exergame among participants with Mild dementia or PD , assess their acceptability of the exergame, and explore the potential usability for further research.

What is the purpose of the research?

The primary purpose of this proposed research is to evaluate the feasibility, acceptability, usability, and experiences of using seated Tai Chi exergame. The study will provide information about the feasibility of using this exergame for the potential improvement of balance, reduction of the risk of falls, and improvement of frailty through non-immersive Tai Chi exergame where participants do not need to stand or wear any instruments.

Do I have to take part?

There will be a total of 6 participants who will take part in this research. It is up to you to decide if you would like to participate in this exergame. If you choose to participate, you will be assessed for the eligibility screening prior to participating in this research. This includes the use of Mini Mental State Examination (MMSE) and Frailty assessment scores to check your cognitive status and frailty level. If you have a MMSE score between 18 to 24 and a Frailty score of 3 or more, then you will be eligible to participate in this study and you will be asked to sign a consent form prior to study participation. Even if you consent, you can withdraw at any time without giving a reason. You can decide not to be part of the study or drop out at any time without penalty or consequences. Withdrawing from the study will not affect your care provided by Ontario Shores Centre for Mental Health Sciences.

You will be given information that is relevant to your decision to continue or withdraw from participation. If you withdraw from the research project at any time, you need not offer any reason for making this request. You may withdraw from the study before we have anonymized and aggregated your data, which will take up to two weeks to do so after data collection. The researchers can be contacted within those two weeks to withdraw your data. Please note it is not feasible to withdraw your results once your data has been anonymized and aggregated, as it will be impossible to trace it back to you after the elimination of direct identifiers. It will also be difficult, if not impossible, to withdraw results once they have been published or otherwise disseminated. You can contact the researcher to withdraw via email address and/or phone number provided on the consent form.

What will happen if I decide to take part?

You will participate in a 30-minute exercise program. Here, you have to follow some basic slow Tai Chi exercises instructed by a virtual instructor shown on the screen. There will be two sessions of exercise every 10 minutes, with a 5 -minute pre-stretching period, 5-10 minutes break between 2 sessions, and 5 minutes post-warm-up exercise. Please note that, in the exercise program, you do not need to stand or wear any VR headset.

Questionnaires

You will be asked to provide information about yourself (e.g., age, gender, living situation) and complete a brief demographics questionnaire before the start of the exercise. This short questionnaire will provide some information about you to help us better understand the research data. After the exercise program, you will answer a series of closed and open-ended questions regarding the feasibility and usability experiences of the exergame. The questions will take about 10-15 minutes to complete. Also, there will be a short interview (15-20 minutes) after the session to get in-depth knowledge about your

perceptions of using the exergame. This interview will be audio recorded upon your consent for future data analysis.

The total expected duration of participation in this research is 60- 70 minutes.

Please note that the information you provide is for research purposes only and will remain strictly confidential.

What are the potential benefits of taking part?

The outcome of this feasibility research will provide you with a collection of potential useful Tai Chi movements that you will be able to practice despite your physical limitation.

This study will provide you the opportunity to engage and interact in a safe, easy to perform, affordable VR-based exercise program during your time of participation. Your experience and descriptive thoughts about completing the exercise session will explicate your perspectives regarding the acceptability of this exergame.

This session could potentially be regarded as a trial use of VR technology for you if you are looking for a cheaper alternative for daily exercise at home with less supervision (i.e., without the need for an in-person guided physiotherapist or occupational therapist). Moreover, immediately after completing the Tai Chi exergame, you may experience some short-term benefits such as a reduced feeling of short-term anxiety, improved mood, and improved sleep.

This research will provide you the opportunity to engage in an exercise program by interacting with VR. As this exergame offers real-time feedback, you will receive an immediate feedback score of their movements. At the end of the session, you will receive an overall score. In future if you continue this exercise, this score will help you to gauge the condition of your upper body posture. A higher/improved score will indicate a better fitness level, while a lower score will suggest otherwise. The improved scores could potentially help to improve balance and strength to decrease your fall risk and frailty levels in the long-term. This has the potential to positively impact your quality of life and may improve your physical and mental well-being.

What are the potential risks or discomforts of taking part?

You will conduct the Tai Chi movements while sitting down using your upper-body joints (shoulders, elbows, wrists, arms, and head). The lower-body joints (hips, knees, ankles, and feet) will not be part of the exergame. This will minimize the chance of any adverse events (such as vertigo risk of fall). We will arrange seats with good back support for this purpose. While Tai Chi involves slow movements, you may experience minor aches on

your hands and shoulder. If there is any physical distress arises during the exercise program, we will take a break. You can rest and will continue when you wish to do. Also, a physiotherapist/nurse will be available who will not be directly involved as a researcher. The role of the physiotherapist/nurse is to monitor any adverse events during the exercise session and always help the participants during the exercise program. Therefore, the physiotherapist/nurse will intervene only if the participant is required any physical support. All appropriate safety measures will be implemented to prevent adverse events, such as the therapist staying close to the participant during the exercise program (less than 1 meter apart) to monitor the participants' movements. The principal investigator and co-investigator will also be available.

There is minimal potential for psychological risk associated with this study. The interview questions that will be asked to you may trigger memories of your lived experiences about the challenges of coping with your disease. If there is any emotional distress that arises during the sharing of your experiences, we will take a break and will resume the interview if you wish to continue. Also, you have the right to withdraw from the interview at any point if you're not comfortable doing so. You will be advised to consult with counseling and support services- Alzheimer Society of Durham region Caregiver Support Group and Hotline, Whitby, Ontario, if required by calling (905) 576-2567.

Will my participation in this project be kept confidential?

The information collected from you during the research will be kept confidential. Your confidentiality will be protected to the extent permitted by the law. You will not be identified in any reports or publications.

Authorized representatives of the following organizations may look at your original (identifiable) study records:

- Research team at Ontario Tech University.
- The Ontario Shores Research Ethics Board, which oversees the ethical conduct of this study.

All the organizations listed above are required to have strict policies and procedures to keep the information they see or receive about you confidential, except where disclosure may be required by law. The principal investigator will ensure that any personal health information collected for this study is kept in a secure and confidential location as required by law. There are federal and provincial laws that these organizations must comply with to protect your privacy.

If the results of this study are published, your identity will remain confidential. It is expected that the information collected during this study will be used in analyses and will be published/ presented to the scientific community at meetings and in journals.

Even though the likelihood that someone may identify you from the study data is minimal, it can never be eliminated.

As mentioned above, the interview will be audio-recorded, you will be notified of the use of the audio recorder before starting the interview, and a verbatim transcript of your answers will be provided to you for review upon request. Pseudonyms will be used to preserve your anonymity, and the data will be kept in a secure, password-protected location (Google Cloud) at all times, accessible only by the researchers named above. It will not be used for any educational purposes.

Who will have access to the data, and where will it be held?

All data will be held securely at Ontario Tech University under the supervision of Dr. Winnie Sun. The data will be stored for five years for future research purposes. Data will be stored in a password-protected computer server (Google Cloud) at Ontario Tech University. No one outside the research team will have access to the individual data collected. Data will be presented in a grouped form to ensure the confidentiality of all participants.

If you decide to withdraw from the study prior to the study concluding, any data collected of you before the withdrawal will be discarded and not stored anywhere. Please note it is not feasible to withdraw your results once your data has been anonymized and aggregated, as it will be impossible to trace it back to you after the elimination of direct identifiers. It will also be challenging to withdraw results once they have been published or otherwise disseminated. You can contact the researcher to withdraw via email address and/or phone number provided on the consent form within two weeks once the data has been collected (prior to data being anonymized and aggregated).

What will happen to the results of the research project?

The findings will be written up for publication in academic journals and will be presented to national and international audiences at conferences. Participants will not be identifiable in any of the reported material. There is no plan for the commercialization of the result right now. If there is any intention for commercialization in the future, a partnership agreement will be developed to address this concern. Ontario Shores and Ontario Tech University will have joint ownership of any results that would come from this study. You will not receive any financial benefits that might come from the results of this study. A copy of the results (one-page fact sheet) will be shared with you for your knowledge if you wish to.

Compensation:

You will receive a $20 gift card to Tim Hortons as a token of appreciation at the end of the interview.

Participant Identification Number for this project: **Please initial the box**

1. I confirm that I have read and understood the above information explaining the research project, what is being asked of me, and I have had the opportunity to ask questions about the project. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. ☐

3. I understand that if I were to become ill or physically injured because of being a participant in this study, medical treatment would be provided. In addition, this consent form does not limit my legal rights or the legal or professional responsibilities of the investigators or involved institutions. ☐

4. I understand that my responses will be kept strictly confidential by the research team. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. ☐

5. I allow myself to be audio recorded during the interview. ☐

6. I would like to review a transcript of my interview.
   □ Yes □ No
7. I agree to take part in the above research project, and I will receive a signed copy of this form.

8. I wish to have a copy of the results (one page fact sheet) via email/mail - _____

_____ _____ _____

Name of Participant Date Signature

_____	_____	_____
_____	_____	_____
Name of Person	Date	Signature

Obtaining Consent

To be signed and dated in the presence of the participant, and a copy of the signed form is to be given to the participant.

Any further questions?

If you have any questions or require further information about the study before or during participation, you can contact the Principal Investigator, Dr. Winnie Sun, at 905-721-8668 ext. 5349.

If you have any questions about your rights as a participant and ethical issues in the research, please contact the REB Chair, Becky Greenberg, at 905-430-4055 ext. 6004.

APPENDIX E: Demographic Data Form for Persons with Mild Dementia or PD

Please tell us the following information about yourself:

1. I am a person living with-

   a. Parkinson's Disease †

   b. Mild dementia †

   c. Both †

2. What is your age range?
   a. 55-59 †
   b. 60-65 †
   c. 66-69 †
   d. 70+ †

3. What is your gender? Male† Female† Other†

4. I have been suffering from Parkinson's Disease and/or Dementia for _____ years.

5. What is the highest level of education completed?

   a. No formal education †
   b. High school †
   c. College †
   d. University †

6. Number of near falls in last one year-
   _____times

7. Number of actual falls in last one year-
   _____times

8. Are you currently taking Levodopa for Parkinson's disease?
    a. Yes
    b. No

9. Do you have any previous experience with the virtual game?
    a. Yes
    b. No

10. Are you comfortable with the virtual game?
    a. Yes
    b. No

11. Do you have any experience with exercising Tai Chi?
    a. Yes
    b. No

12. What type of physical exercise do you do, if any? _____

13. How many times you do exercise weekly, if any? _____

_____

_____

Appendix F: Feasibility, Acceptability, and Usability of Seated Tai Chi exergame: Survey questionnaire for persons with mild dementia or PD

Thank you for your participation in this survey. Your participation is voluntary, and you can answer only those questions that you are comfortable with. Your participation will be kept anonymous. Also, your response will be confidential. Your feedback on the use of seated Tai Chi exergame will help us to explore the opportunities to improve the fall rate and frailty level and improve your physical function by providing you with an insight into the potential use of seated Tai Chi exergame.

Please read the statements below and select the best options that describe your experience of the usability and acceptability of seated Tai Chi exergame:

1. I found this seated TC exergame enjoyable:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

2. I feel motivated after performing this seated TC exergame:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

3. I feel comfortable performing this seated TC exergame:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree

e) Strongly disagree

4. This exercise program will help me in the improvement of balance and strength:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

5. This exercise program will help in the prevention of falls:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

6. I found this seated TC exergame easy to operate:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

7. I found this seated TC exergame safe:
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

8. I am satisfied with performing this seated TC exergame:
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

9. I experienced discomfort after performing this seated TC exergame:
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

10. I felt fatigued after performing this seated TC exergame:
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

11. I felt pain in my limbs after performing this seated TC exergame:
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

12. The movements of this exercise program are easy to perform:
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

13. I can perform this seated TC exergame _____ times a week.

14. I can perform this seated TC exergame for _____ mins a day.

15. I would be interested in continuing using this seated TC exergame in the future:
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

Appendix G: Interview Guide for Persons with Mild Dementia or PD

Title of Research Study:

The Feasibility, Acceptability, and Usability of Seated Tai Chi Exergame among Frail Older Adult with Mild dementia or Parkinson's Disease: A Pilot Study.

Introduction:

Good morning/Afternoon,

How are you today?

First of all, I would like to thank you for your time to do this interview today.

My name is Farzana, and I would like to talk to you about your seated TC exergame experiences.

This interview should take about 15-20 minutes, and I will be audio recording the session so I do not miss out on any of your responses. Because we'll be audio recorded, feel free to provide your answer as elaborately as possible, so we don't miss anything when transcribing your responses. Your responses will be kept confidential. Your responses will only be shared with research team members, and we will make sure that whatever information we include in our report does not identify you in any way. You do not have to talk about anything you don't want to, and you may end the interview at any time.

Please read through it carefully and sign at the bottom to provide informed consent to participate in this study. You will be provided a copy of this signed consent form.

If you have any questions, please feel free to ask me.

Interview Questions:

1. Could you kindly share your physical exercise experiences nowadays? (What are the physical exercises you like, if any/ If you do not exercise, why?)

2. Could you kindly share your fall history in the past six months? (How, if any, did fall affect your emotional well-being along with physical well-being?)

3. What was your experience in participating in this exergame? You can talk about anything related to this session, for example, whether you liked it or not; and

whether you found it helpful or not. (What you liked, disliked, and why; what was useful or not helpful and why?)

4. Were the instructions for the seated Tai Chi exergame easy to follow? Why or why not? (i.e., sequence, the wording of the instruction)

5. What is the likelihood that you will take part in this exergame session in the future?

6. Is the practice session appropriate and suitable for you? (i.e., would you rather practice this exergame alone or in a group setting?)

7. What are your thoughts on this virtual Tai Chi program in comparison to the in-person exercise program? (Which one is more convenient/ enjoyable/ preferable? Why?)

8. Do you have any suggestions about how we can increase your exercise program participation with your loved ones?

Conclusion:

(End audio recording.) Okay, I'll be transcribing this audio recording into a verbatim transcript. If you like, I could contact you and let you review it to ensure we capture your responses accurately in the near future. Thereafter, this data will be used to develop a report on the research findings. If you're interested in remaining updated with this study, feel free to get in touch with me using the contact information provided.

Thank you so much for your time.

Appendix H: Feasibility, Acceptability, and Usability of Seated Tai Chi exergame: A Task Assessment survey for Persons with Mild dementia or PD

Participant's ID: **Date:**

1. Start time:
2. End time:
3. Frailty score:
4. MMSE score:
5. Duration of exercise dose one:
6. Duration of the break between exercises:
7. Duration of exercise dose two:
8. Performance score of exercise dose one:
9. Performance score of exercise dose two:
10. Total time of completion of the task: _____ min
11. Time required to learn the technology: _____ min
12. Reported adverse events (if any): _____

Note: This form will be completed by the researcher

Appendix I

Frailty index

Week grip strength	Cut off points for grip strength of the dominant hand is as following, =17 kg for BMI =23 =17.3 kg for BMI 23 < BMI 26 =18 kg for BMI 26 < BMI 29 =21 kg for BMI >29
Slow gait speed	The subject could use a walking aid, but not the aid of another person. Walking 4m (speed) in: =0.65 m/s for height =159cm =0.76 m/s for height >159 cm
Low physical activity level	Global Physical Activity Questionnaire (GPAQ) according to WHO (2012) recommendation was used to determine the physical activity level.
Self-reported exhaustion	Indicative positive response of any one out of three questions. a. Felt unusually tired in the previous month? (low energy level <3 {on of scale of 0–10}) b. Felt unusually weak in the previous month? c. Had an unusually low energy level? (For b. and c., most or all the time {where, rarely [<1day], some or little of the time [1–2 days], most of the time [3–4 days] and all the time})
Low weight	BMI <18.5 kg/m², which is the lowest category WHO BMI classification.

Appendices J

Table I

Inclusion criteria	Exclusion criteria
Older adult aged 55 or more	Older adult less than 55 or more
English written literature	Non-English written literature
Recently published literature (from January 2000 to June 2020)	Published literature before January 2000
Inclusion Criteria of the target population: • Participants with PD or mild dementia or older adults with wheelchair assistance. • History of fall or near fall in the last year. • Satisfactory mini-mental status score (MMSE) between 18-24. • Must be able to communicate in English.	Exclusion criteria of the target population: • Those who have severe visual or auditory abnormalities or any other cardiac abnormalities. • Those who have severe dementia. • Those who will not be able to communicate in English. • Participants with a history of drug that may alter their balance. • Any recent injury that prevents participation in exercises; Exercise contraindications such as recent myocardial infarction or electrocardiography changes, complete heart block, acute congestive heart failure, unstable angina, and uncontrolled hypertension.
Exercise programs must incorporate fall prevention/balance/cognitive improvement.	
VR Exercise programs that target balance or cognitive improvement.	