Using Active Video Games to Improve Physical Literacy Levels in Older Adults: A Mixed-Methods Approach

Campelo, Alexandre Monte

http://hdl.handle.net/1880/112676

Downloaded from PRISM Repository, University of Calgary
Using Active Video Games to Improve Physical Literacy Levels in Older Adults:

A Mixed-Methods Approach

by

Alexandre Monte Campelo

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

GRADUATE PROGRAM IN KINESIOLOGY

CALGARY, ALBERTA

OCTOBER, 2020

© Alexandre Monte Campelo 2020
Dedication

I dedicate this thesis to my loving family, who never wavered in their support and guidance. My mother, Darlene, who always lent an ear and instilled in me the mantra “one step at time and everything will be fine”; My father, José Arnaldo, who’s words of wisdom will remain with me throughout my life; And my brother, Gustavo, who was always there with a good piece of advice to get me always on track.
Acknowledgements

I am in debt to the invaluable contribution of:

- My supervisor and co-supervisor, Dr. Larry Katz and Dr. Dwayne Sheehan, for their continued motivation and direction. Their knowledge and expertise always put me on the right track and inspired me to be better.

- My supervisory and defence committee members, Dr. Kathryn Schneider, Dr. James Parker, Dr. Nathan Hall, and Dr. Jackie Sieppert, for their insights and perspectives to this thesis.

- The Sport Technology Research Lab (STRL) team at the University of Calgary staff for their time and commitment.

- The participants of the studies. Their smiles, commitment, and genuine enjoyment of the study made every day much more pleasurable.

- The colleagues who were directly or indirectly involved with the studies and my PhD Program. I could not go through all this journey by myself and every single help has been greatly appreciated.

- The Coordination for the Improvement of Higher Education Personnel (CAPES) and STRL for funding my research.
"Strength does not come from physical capacity.

It comes from an indomitable will"

- Mohandas Karamchand Gandhi
Preface

Each of the following four chapters are based on scientific manuscripts:

**Chapter Three:**


**Chapter Four:**

Campelo, A. M., Weisberg, A. D., Schneider, K., & Katz, L. (2020). The Effects of Exergame Training on Community-Dwelling Seniors’ Physical Literacy: A Randomized Controlled Trial.

**Chapter Five:**

Table of Contents

Dedication .................................................................................................................................................. i
Acknowledgements ................................................................................................................................. ii
Epigraph ......................................................................................................................................................... iii
Preface............................................................................................................................................................... iv
Table of Contents ........................................................................................................................................ v
List of Tables .................................................................................................................................................. ix
List of Figures ................................................................................................................................................ x
List of Abbreviations .................................................................................................................................... xi
Abstract........................................................................................................................................................... 1

Chapter One: Introduction .............................................................................................................................. 2
1.1 Background and Motivation ...................................................................................................................... 2
1.2 Research Questions .................................................................................................................................... 6
1.3 Thesis Outline ............................................................................................................................................. 6

Chapter Two: Literature Review .................................................................................................................... 8
2.1 Physical Literacy and the Aging Process .................................................................................................... 8
2.1.1 Physical Literacy Development and Active Aging .............................................................................. 8
2.1.2 Older Adults’ Sedentary Behaviour and Increased Mortality Rates .................................................. 13
2.1.3 Efforts Towards a Practical Physical Literacy Model for Older Adults .............................................. 16
2.2 The Use of Active Video Games as Physical Activity Tools .................................................................... 19
2.2.1 Traditional and Active Video Game Interventions for Older Adults .................................................. 27

Chapter Three: Using Active Video Games to Improve Older Adults’ Physical Literacy: A Theoretical Approach .................................................................................................................. 29
3.1 Abstract ...................................................................................................................................................... 29
3.2 Introduction ................................................................................................................................................. 29
3.3 Literature Search Strategy ........................................................................................................................ 32
3.4 Fundamentals of Physical Literacy .......................................................................................................... 32
3.5 Virtual Reality Exercise Games .............................................................................................................. 36
3.6 An Ecological Approach to Use Active Video Games to Optimize Physical Literacy .......................... 42
3.7 The Interrelated Cognitive Factors ......................................................................................................... 46
3.8 The Interrelated Affective and Behavioural Factors ................................................................................. 48
3.9 The Interrelated Physical Factors ................................................................. 51
3.10 Future Directions ......................................................................................... 53
3.11 Conclusion .................................................................................................... 58
3.12 Acknowledgements ..................................................................................... 59

Chapter Four: The Effects of Exergame Training on Community-Dwelling Seniors’
Physical Literacy: A Randomized Controlled Trial ........................................... 60
4.1 Abstract ........................................................................................................... 60
4.2 Introduction ..................................................................................................... 60
4.3 Method ............................................................................................................ 64
4.3.1 Study Design ............................................................................................... 64
4.3.2 Sample and Selection Criteria ................................................................. 65
4.3.3 Intervention Programs ............................................................................. 66
4.3.4 Outcome Measures ................................................................................... 69
4.3.5 Data Analysis ............................................................................................. 73
4.4 Results ............................................................................................................ 74
4.4.1 Demographics ............................................................................................ 74
4.4.2 Functional Mobility .................................................................................... 76
4.4.3 Confidence .................................................................................................. 77
4.4.4 Knowledge and Understanding ................................................................. 77
4.4.5 Motivation .................................................................................................. 78
4.4.6 Daily Step Count ....................................................................................... 80
4.5 Discussion ....................................................................................................... 80
4.6 Limitations ..................................................................................................... 83
4.7 Conclusion ...................................................................................................... 85

Chapter Five: Older Adults’ Perceptions of the Usefulness of Technology for
Engaging in Physical Activity: Using Focus Groups to Explore Physical Literacy .... 86
5.1 Abstract ........................................................................................................... 86
5.2 Introduction ..................................................................................................... 87
5.2.1 Objective .................................................................................................... 89
5.3 Materials and Methods ................................................................................ 89
5.3.1 Study Design ............................................................................................... 89
List of Tables

Table 3.1. The relationship between the physical literacy concept and the implementation of AVG in healthcare.......................................................... 45

Table 4.1 Demographic variables’ means, standard deviation, and analyses of variation between groups. ........................................................................ 75

Table 4.2 Variables’ means, standard deviations of each group, and comparison within groups by phases of the study. .......................................................... 75

Table 4.3 GEE Test of Model Effects of each dependent variable.............................. 76

Table 4.4 MPAM-R Subscales’ means, standard deviations of each subscore, and comparison within groups............................................................. 78

Table 4.5 GEE Test of Model Effects of each MPAM-R Subscales.............................. 79

Table 6.1 Summary of the findings according to each PL domain............................. 118
List of Figures

Figure 2.1 Physical Activity Vs. Chronic Disease Cycle .................................................. 14
Figure 2.2. Physical Literacy Model for Older Adults: An Ecological Approach .......... 19
Figure 3.1 Main factors to consider when using AVG as an exercise tool....................... 38
Figure 3.2 AVG Implementation Model........................................................................ 42
Figure 3.3. Perspectives, design considerations for implementing AVG into PA programs, and possible outcomes. ................................................................. 56
Figure 4.1 Flow chart of subjects’ recruitment and follow-up assessment. ................. 66
Figure 4. 2 Timed Up and Go Performance of each group by phase of the study........... 77
Figure 4.3 MPAM-R Fitness-Health subscores of each group by phase of the study....... 80
Figure 5.1 Themes and subthemes that emerged from the discussions of each focus group. ........................................................................................................ 95
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACSM</td>
<td>American College of Sports Medicine</td>
</tr>
<tr>
<td>ADL</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>AVG</td>
<td>Active Video Games</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>CT</td>
<td>Conventional Training</td>
</tr>
<tr>
<td>DF</td>
<td>Degrees of Freedom</td>
</tr>
<tr>
<td>EE</td>
<td>Energy Expenditure</td>
</tr>
<tr>
<td>ECS</td>
<td>Exercise Confidence Survey</td>
</tr>
<tr>
<td>ET</td>
<td>Exergame Training</td>
</tr>
<tr>
<td>FMS</td>
<td>Fundamental Movement Skills</td>
</tr>
<tr>
<td>GEE</td>
<td>Generalized Estimating Equation</td>
</tr>
<tr>
<td>IPLA</td>
<td>International Physical Literacy Association</td>
</tr>
<tr>
<td>K&amp;UQ</td>
<td>Knowledge and Understanding Questionnaire</td>
</tr>
<tr>
<td>MPAM-R</td>
<td>Motives for Physical Activity Measure – Revised</td>
</tr>
<tr>
<td>NT</td>
<td>No Training</td>
</tr>
<tr>
<td>PA</td>
<td>Physical Activity</td>
</tr>
<tr>
<td>PL</td>
<td>Physical Literacy</td>
</tr>
<tr>
<td>QOL</td>
<td>Quality of Life</td>
</tr>
<tr>
<td>RCT</td>
<td>Randomized-controlled Trial</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>TUG</td>
<td>Timed Up and Go Test</td>
</tr>
<tr>
<td>VE</td>
<td>Virtual Environment</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Abstract

The concept of physical literacy has become widely adopted in the past few decades into education, sport, and recreation to support active and healthy lifestyles. Concomitantly, the advancement of technologies, especially those in wearable activity trackers and active video games, has allowed mind-body integrated physical activity, preventing sedentary lifestyles. The implications of technologies to physical literacy seem promising, however, they have been mostly explored in children and youth populations. This thesis explores, in six chapters, the use of active video games in a structured exercise program for older adults in order to improve their physical literacy. The first chapter introduces the thesis topics, the research questions that this thesis seeks to answer. Chapter two presents the relevant literature on the benefits and challenges of using active video games for physical activity promotion, functional skills maintenance, injury, and chronic diseases prevention in the elderly. Based on the literature background, chapter three presents an ecological model to implement active video games as part of exercise programs to improve older adults’ physical literacy. In order to understand the effects of active video game training on older adults’ physical literacy, chapter four presents a randomized controlled trial conducted with community-dwelling older adults. From a total of 40 participants who completed the trial, 15 were selected to provide their perceptions of using technologies to engage in physical activity, which was addressed in chapter five. The mixed-method analysis demonstrated the feasibility of using technologies to improve older adults’ physical literacy, and chapter six summarizes the overall results, limitations, and recommendations for researchers, healthcare providers, policymakers, and technology designers.
Chapter One: Introduction

1.1 Background and Motivation

The senior population is the fastest growing age group worldwide. Over the last six decades, the increasing life expectancy and declining fertility rates have led to an aged population worldwide (Murray et al., 2018). According to World Population Prospects from the United Nations (2019), by 2050, approximately two billion people (~16.6%) of the world’s population will be over the age of 65, up from 900 million (~9%) in 2019. In Canada, there are more older adults than children, and by 2050, approximately 30% of Canadians are expected to be older adults (Statistics Canada, 2017). The aging of the world’s population represents one of the key societal challenges, which requires an urgent response from researchers, professionals, and the wider society. In order to respond to this challenge, there is a need to support and create integral opportunities for longer and healthier lives (Zaninotto, Head, & Steptoe, 2020).

The aging process is characterized by a natural and progressive decline of physical and cognitive functions, leading to potential vulnerabilities such as multiple chronic diseases, functional impairments, and social isolation. The fast growth in this age group, associated with increased health concerns, certainly adds more pressure on healthcare systems to cater to their needs (Bohnert, Chagnon, & Dion, 2014). According to the World Health Organization (WHO, 2018), strategies to achieve healthy aging include healthy daily habits, such as social participation, interaction and conviviality, adequate sleep, emotional management, balanced diet, and regular cognitive and physical activities.
Given the importance of considering behavioural, physical, cognitive, affective, and social domains to pursue healthy aging, the holistic concept of physical literacy (PL) provides a powerful framework to understand and translate the interaction between physical activity (PA) and motor skill outcomes, and broader social, cognitive and affective processes (Cairney et al., 2019). Despite the availability of a variety of definitions, PL has been consensually defined as the development of motivation, confidence, physical competence, knowledge, and understanding to value and engage in a wide variety of physical activities and environments that benefit the person as a whole (Whitehead, 2014). PL ultimately aims to develop the human-embodied potential and promote lifelong engagement in PA, however the literature is most established in describing PL in children and youth.

PA is defined as bodily movements produced by skeletal muscles that require energy expenditure and fitness (Caspersen, Powell, & Christenson, 1985). In healthy older adults, regular practices and adequate levels of PA can improve cognitive and physical functioning, such as memory, attention, inhibition, processing speed, mood, mobility, fine and gross motor control, muscular and cardiorespiratory fitness, bone density, among others. Besides improving general cognitive and physical functioning, PA also reduces anxiety levels, sleep dysfunctions, perceived stress, risk of depression, hypertension, coronary heart diseases, stroke, diabetes, a variety of cancers (including breast cancer and colon cancer), falls and hip or vertebral fractures, and is fundamental to energy balance and weight control (Hortobágyi et al., 2015; Kelly et al., 2014; Kramer & Colcombe, 2018; Mian, Baltzopoulos, Minetti, & Narici, 2007; Voelcker-Rehage & Niemann, 2013).
Despite well-documented evidence that PA is linked to health and wellbeing, regular PA engagement decreases with age (Koolhaas et al., 2017; van Ballegooijen, van der Ploeg, & Visser, 2019). The American College of Sports Medicine (ACSM, 2013) recommends at least five times per week for 30 min (or 150 min per week) of light-to-moderate exercise, or more vigorous exercise, a minimum of 60 min per week. Research on PA behaviour suggests that most older adults do not meet such recommended amounts of PA (Azagba & Sharaf, 2014; Townsend, Wickramasinghe, Williams, Bhatnagar, & Rayner, 2015). A decreased amount of PA levels, or a sedentary lifestyle, further impacts both physical and cognitive functions and increases the epidemiology of chronic diseases and risk of injuries, severely challenging a healthy aging process (Colley et al., 2011; Haley & Andel, 2010). The stimulation of regular practice of PA among older adults may help develop a sense of self, relationships with others, and knowledge and understanding of PA. Moreover, older adults may increase their confidence levels, which reflects beyond PA settings into everyday life. A higher level of confidence when performing PA may have a positive effect on older adults’ motivation to adhere regular PA practices (Jones et al., 2018).

There has been an increasing acknowledgement of the importance of PA in relation to an individual’s health status (Buecker, Simacek, Ingwersen, Terwiel, & Simonsmeier, 2020; Lucas et al., 2020). PL could be the elusive factor that will make a successful and sustained increase in PA participation by older adults (Jones, 2018). Over time, PL may fluctuate or diminish, depending on factors such as PA behaviour, health status, age, participation in sports, workplace demands, daily habits, and preferred interests (Jones et al., 2018). Although PL may be developed at any age, it typically takes more time and
practice for older adults when compared to their younger peers, or to their own childhood or teenage years (Whitehead, 2013). In order to help older adults’ PL development, an innovative approach may be necessary.

In the last decade, researchers have tested innovative technologies, such as wearable fitness trackers and virtual reality to motivate engagement in PA and have found promising results (Burton et al., 2018; Johnson et al., 2019). According to MacDonald, Rizzone, and Vengal (2020), such technologies offer a unique way to potentially increase regular PA participation while also improving PL levels. Technologies in exercise settings allow the participants to better control their environments and engage themselves through challenging games. For example, wearable fitness trackers are being used to correlate older adults sedentary to demographic and health-related factors (Dohrn, Gardiner, Winkler, & Welmer, 2020). In its turn, virtual reality (VR) gaming systems involving movement, often called active video games (AVG) or exergames, demand from the player physical interaction with a virtual environment. It has been shown that AVG have multiple benefits for physical and cognitive health, supporting the development of PL (Chen, Jeng, Fung, Doong, & Chuang, 2009; Fu, Gao, Tung, Tsang, & Kwan, 2015; Gamberini, Alcaniz, et al., 2008; Sheehan & Katz, 2010, 2011). Positive changes in older adults’ PL levels by using technologies may further improve their overall health status, prevent injuries, or delay risks of illness.

Wearables and VR technologies usually generate quantitative data that is used by researchers, designers, and health care providers to rely on objective information about performance. However, quantitative data analysis may not reveal the indicators that determine the quality of participants’ experiences and their relationship to those
technologies. Qualitative methods may expand the opportunities for understanding the utilization of technology to older adults’ PL development. Therefore, this exploratory research investigates the use of technologies in exercise programs for older adults, and the effects on their PL levels.

1.2 Research Questions

The primary question which this thesis seeks to answer is, “How can active video games be implemented as an effective approach to enhancing older adults’ physical literacy?” Further secondary questions include: “How does an active video game-based exercise program for older adults affect their physical literacy?”; and “What are participants’ perceptions of the technology-based exercise programs as a way to improve physical literacy?”.

1.3 Thesis Outline

This document is a manuscript-based thesis, composed of six chapters, wherein chapters three to five include original manuscripts as results of research studies that were conducted to answer the proposed research questions. The content of the remaining chapters is briefly described as follows:

Chapter one includes an introduction with background information and presents the thesis research questions.

Chapter two presents a selected review of the relevant literature related to the thesis topics. It provides a review on the use of active video games on older adults’ physical literacy development.
Chapter three includes a conceptual manuscript that provides a theoretical approach to the use of active video games to improve older adults’ physical literacy.

Chapter four includes a manuscript reporting the results of a randomized controlled trial designed to evaluate the use of active video games in an exercise program for older adults, and the benefits on their daily exertion, mobility skills, confidence, motivation, and knowledge about physical activity.

Chapter five includes a manuscript which aimed to investigate older adults’ perceptions of the use of active video games and wrist worn activity tracker to engage in physical exercise programs.

Chapter six summarizes the significant findings of this thesis. General conclusions are discussed, and possible future work is proposed.

This thesis is based on a collection of manuscripts, and therefore has some redundancy in the sections.
Chapter Two: Literature Review

2.1 Physical Literacy and the Aging Process

2.1.1 Physical Literacy Development and Active Aging

PL is consensually defined by the International Physical Literacy Association (IPLA, 2015, p. 1) as “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life”. According to Tremblay and Lloyd (2010, p. 28) PL is the “foundation of skills or tools - social/cognitive, behavioural, and fitness related - that children need to possess or develop in order to receive the inherent benefits of taking part in physical activity and sport for life-long enjoyment and success.”

In general, PL development occurs in early childhood and progress throughout one’s life through active living behaviour (Sun, 2015). From an early age, the development of a set of gross motor skills, called fundamental movement skills (FMS), allow children to move confidently and with control in a wide range of activity settings (Bai et al., 2020; Egert, Dederer, & Fukkink, 2020). FMS are defined as “basic locomotor, non-locomotor and manipulative skills (such as running, stretching and throwing) that require voluntary body and/or limb movements” (Steven-Smith, 2016, p. 7). FMS development is then critical to establishing the foundation for play, enjoyment, recreation, participation in many sports, and to effectively respond to environmental demands (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Exposing children and youth to movement skills that have the greatest capacity to transferability and cross-activity participation enables the widest possible participation outcomes across the lifespan (Dudley et al., 2017). Ultimately, the
integration of FMS development to increased PA participation, enjoyment, body-awareness, and socialization, will enhance lifelong PL (Jakobi, Dempsey, Hellsten, Monette, & Kalmar, 2020; Jones et al., 2018). FMS, PA, and PL are fundamentally linked as those who are able to perform, enjoy and participate in PA in a variety of environments are more likely to have the skills, fitness, motivation, and knowledge to continue this positive lifestyle throughout their life.

Understanding the development of FMS in early life could be complemented by understanding the maintenance or retraining of functional movement skills in the elderly (Jones & Stathokostas, 2016). The development of FMS is age-related but not age dependent (Gardner, 2017). Whitehead (2013) described chronological stages of life that relate to PL development. These stages depend on factors, such as regular practices, previous experiences, personal rate of development, interests, and they do not have necessarily clearly marked limits to PL maintenance. From a psychosocial perspective, exposure to a variety of PA experiences that challenge different motor skills should be provided early during FMS development (Kalaja, Jaakkola, Liukkonen, & Watt, 2010). The opportunities created for active behaviour, such as group activities and activities in different environments, often increase receptivity to active living (Speros, 2009). However, potential barriers, such as frustrations and failures to perform PA, lack of time, confidence, motivation, and support from others, ageism and negative perceptions of own age, few sports facilities and PA opportunities, among others are reported by older adults to be reasons for PA disengagement (Brownson, Baker, Housemann, Brennan, & Bacak, 2001).

Researchers, practitioners, and policy makers have increased their adoption of PL concepts (Dudley et al., 2017), and explicit conceptual links between PL and health have
been proposed (Cairney et al., 2019). For instance, Canadian provincial governments have acknowledged the potential of developing PL programs to possibly prevent obesity by improving school curriculums and promoting sport participation (McKean, 2013). Through programs, such as the Long-Term Athlete Development Model using the Physical Literacy Assessment for Youth (PLAY) instrument, children and youth have the opportunity to develop, and have their PL periodically assessed, which allow them to become, and remain, active for life. Although improving PL has been endorsed as having the potential to positively impact the obesity crisis, limited research has been done to determine the multitude of factors that influence a child’s PL development (Liu & Chen, 2020).

The main goal of PL programs, whether they are in formal school settings or in post-curricular educational settings, such as recreation centres, is to promote the desire to continue in PA throughout the lifespan (Roeterts & Jefferies, 2014). This means that programs are built around the “whole person”, encompassing behavioural, physical, cognitive, affective PL domains (Mandigo et al., 2009). In a review conduct by Castelli, Centeio, Beighle, Carson, and Nicksic (2014), comprehensive school PA programs were assessed according to their impact on children’ PL levels. From an inclusive sample of 16,000 students, those who had access to playgrounds and after-school activities were three times more likely to be active. The authors justified their findings by stating that programs which included childcare, sports, and structured physical activities resulted in enrichment of health-related fitness knowledge (Castelli et al., 2014). Castelli et al., (2014) also described the lack of a single method for PA promotion within primary schools as a major limitation, as there was no comparable measure.
Beighle, Erwin, Morgan, and Alderman (2012) investigated if the number of steps taken by school children were different based on season, as well as based on time spent in-school and out-side of school. This study was conducted for the purpose of prioritizing resources and interventions based on deficits found in PL. It was found that of the 105 students, steps taken in the winter months were typically lower and associated with limited daylight, and the lack of in-school and out-of-school activities available to the student based sampled (Beighle et al., 2012). It was suggested that adding 15-minute recess, or extra physical education (PE), the children could increase up to 600 steps a day. However, the authors pointed out the lack of control in contextual data, such as types of programs being performed by the children within or extra classroom settings, or the exact daily reported weather.

According to the Aspen Executive Summary (Aspen Institute, 2015), PL programs have not been around long enough to produce longitudinal studies evaluating their effectiveness. Yet, a special issue on PL evidence and intervention from the Journal of Teaching in Physical Education, included 10 articles that reported data from PL intervention programs implementation (Dudley, Cairney, & Goodway, 2019). The articles reported findings from research methods using an assessment (Mandigo, Treadway, & Lodewyk, 2019), visually impaired students (Brian et al., 2019), young children (Gu, Chen,&Xianxia, 2019), and the circus arts as intervention medium (Kriellaars et al., 2019) to explore the development of PL in schools.

Children also benefit from the introduction of a PL approach into PE programs. The benefits included: improvements in attitude and behaviour of students towards PA (Caballero et al. 2003); increased frequency of PE lessons (Sollerhed and Ejlertsson,
increased PA during PE lessons (Sallis et al. 1998; McKenzie et al. 1997); increased provision of PE resources (Coleman et al. 2005); and well received professional development (McKenzie et al. 2004). Telford et al. (2020) further investigated how a PL specialist could contribute to improve PE program across an Australian network of schools using PL approach. The modifications on individual and class level included: before or after school games and activities; recess and lunch time activities; adapted activities to suit class level; writing letters to principal explaining why more PA/ time was needed; inventing new and inclusive games which all children could be involved; self-monitoring – ranging from fitness trackers to self-awareness, encouraging thinking and strategizing. The results demonstrated that the grade 5 students were more skillful at certain movements/skills; able to create their own games improved hand-eye co-ordination; increased involvement in community sport; positives attitudes towards PA, choosing PA in free time; improved behaviour, demonstrating calm and more focused in class time; improved teamwork, collaboration, and communication; developed more confidence to perform the proposed activities without the fear of failure; enjoyed the modifications and had fun; more motivated to participate in the proposed activities; and improved problem solving, alone and in a team.

The quality of motor development in early life has a significant impact on the PA behaviours and quality of life experienced in later years (Aspen Institute, 2015). Children with better-developed motor skills are more physically active in the youth and motor coordination is a significant predictor of PA during the grade school years (Williams et al., 2008). In its turn, physically active youth are more likely to stay active through adolescence (Malina, 2012) and into adulthood (Telama et al., 2005). Yet, many are late in
developing the FMS that allow them to feel good about their competence to engage in sports and other activities. In addition, not all FMS are developed equally. In this way, PL requires the development of more than motor skills — it’s also a matter of developing the mindset to use those skills.

PL seems to be gateway to an active aging. Malina (2012) has hypothesized that enhancing movement proficiency among children in general and, at the same time, stimulating their confidence, motivation, and knowledge about PA, would increase levels of regular PA practices in later life, across society. According to the author, the commitment to offer PL programs to all children holds the promise of helping them understand that they can run, jump, hop, skip, throw, catch, and kick, among other movements, which allow engagement in activities that are fun, healthful, and build community (Malina et al., 2012). These findings demonstrate evidence-based examples of how to intentionally target PL as a whole, and the effect this will have on PL and PA levels for life. Furthermore, adopting the concept of PL in national curriculum and PA/sport policy guidelines may be an important step towards active aging.

2.1.2 Older Adults’ Sedentary Behaviour and Increased Mortality Rates

In later life, regular engagement in PA is also influenced by age-related health disorders and lifestyle choices (Taylor & Johnson, 2008). Although aging is a natural and non-pathologic process that affects all individuals, it is characterized by notable declines in physical and cognitive functions, such as balance, gait speed, executive function, episodic memory (Powell & Wahidin, 2006). Decreased physical and cognitive functions affect the competency to perform activities of daily living (ADL), resulting in restrictions of mobility and decision making, social isolation, and lack of confidence and motivation. Long-term
PA avoidance leads to sedentary lifestyles and higher risks of illness and injuries, further reducing the capacity for exercise sustainability following recovery (Fernandes & Zanesco, 2015; Trost, Owen, Bauman, Sallis, & Brown, 2002).

Approximately 20%-30% of global older adults report engaging in regular PA (Bauman, Petersen, Blond, Rangul, & Hardy, 2018; Eime et al., 2016; Hallal et al., 2012). Physical inactivity is recognized as one of the leading risk factors for overweight, obesity, non-communicable diseases, and chronic conditions. It is estimated that 80% of older adults have at least one chronic disease, and 77% have at least two (National Council on Aging, 2016). Sedentary behaviour has been identified as the fourth leading risk factor for global mortality, representing 6% of deaths. Nonetheless, chronic illness, such as cardiovascular, respiratory, and metabolic diseases, caused by physical inactivity along with increasing tobacco use, and poor diet and nutrition, are the leading global causes of death (WHO, 2002) (Figure 2.1).

Figure 2.1 Physical Activity Vs. Chronic Disease Cycle (adapted from International Classification of Functioning, Disability and Health (ICF) framework.)
The most common cause of injuries among the older population is falling. Nearly 40% of older adults fall each year, and this percentage can increase as they age (Blake et al., 1988; Prudham & Evans, 1981; Scott, Herman, Gallagher, & Sum, 2011). Approximately 40% of traumatic injuries-related hospitalizations are due to falls. The direct association between falls and PA levels is inconclusive. However, evidence from population-based and longitudinal studies for the association of PA and risk of falling in community-dwelling older adults demonstrated that the risk of being a recurrent faller (two or more falls over 12-36 months) is 39% higher in those with the lowest levels of PA (Soares et al., 2018). Frequent falls in the elderly can lead to serious consequences, such as pain, bruising, lacerations, fractures, including upper extremity and hip fractures, and intracranial bleeding in severe cases (WHO, 2008). Moreover, 20-39% of older adults who have fallen experience fear of falling, called post-fall syndrome (Scheffer, Schuurmans, Van Dijk, Van Der Hooft, & De Rooij, 2008), which leads to lack of motivation and confidence to move, further limiting their ADL, independent of injury (Campbell, Reinken, Allan, & Martinez, 1981). Thus, it is important to assess older adult’s medical history, understand their motivation to learn a sport or practice PA, in which context they have practiced, and which skills they may need to re-learn.

A sedentary lifestyle associated with high risks of injuries and chronic diseases among older adults has a significant impact on health care systems and are major public health and economic concerns. Injuries and chronic diseases have significant impacts on health care costs due to their high expenses and continuous treatment (Li, Blume, Huang, Hammer, & Ganz, 2015). In 2013, it was estimated that globally ‘physical inactivity’ cost
health care systems INT$54 billion, with an additional $13.7 billion in productivity losses due to physical-inactivity-related deaths (Ding et al., 2016).

Given the higher rates of physical inactivity and their far consequences beyond individual levels, the current literature tends to incorporate a ‘multi-theoretical approach’ to understand older adults’ PA behaviours. Nigg, Borrelli, Maddock, and Dishman (2008) identified four theoretical models that were mostly utilized to understand PA behaviour: ‘Social-Cognitive Theory’, ‘Theory of Planned Behaviour’, ‘Self-Determination Theory’, and ‘Transtheoretical Model’. Grodesky, Kosma, and Solmon (2006) examined the constructs from the ‘Transtheoretical Model’, ‘Theory of Planned Behaviour’, and ‘Self-Determination Theory’ and their association with the different ‘Stages of Change Model’ to understand PA behaviour change among older adults. According to the authors, traditional measures for encouraging the adoption and maintenance of exercise have been relatively ineffective due to the complexity of PA behaviour and the issues facing older adults’ health. According to (McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003), such models are not dedicated to understanding individualized determinants among older adults according to the specific environment where they live. PL, in a sense, unifies previous theories and models from sport/exercise psychology and motor development (Bremer, Graham, & Cairney, 2020). Thus, a PL model for older adults would be a well-coordinated strategy that would combine individually focused actions and environmental-based approaches.

**2.1.3 Efforts Towards a Practical Physical Literacy Model for Older Adults**

According to Jurbala (2015), due to the complexity and philosophical underpinnings, the PL concepts have been interpreted and applied in several different
ways. Whitehead (2010b) has suggested that different approaches to PL are expected. According to the British philosopher, the underlying monist, existentialist, and phenomenologist perspectives are central frameworks for PL concepts. “Monism” is the belief that the mind and body are indivisible but interdependent. “Existentialism” proposes that every individual is a result of their social interactions. The “Phenomenology” underpinning proposes that, through the embodied nature of these social interactions, individuals form their unique perspectives of their own reality (Whitehead, 2007). When it comes to practical implementation, the unique personal experience, personal capabilities at any point in time, and environmental socio-cultural contexts necessitate a context-specific approach. The influence of culture was recognized by (Whitehead, 2010b, pp. 12), who identified that “specific expression (of PL)...will be particular to the culture in which they live”. The cultural differences in interpretation could stimulate the implementation of PL in practice within various settings, ultimately leading to different approaches to practical implications. However, the diversity to interpret PL, accordingly to the culture it has been applied, has generated a level of inconsistency and conflict to the original definition (Dudley, Cairney, Wainwright, Kriellaars, & Mitchell, 2017; Jurbala, 2015; Tremblay & Lloyd, 2010).

Because of the number of variables to be practically considered in order to determine if an individual is physically literate or not, PL assessment has been difficult to standardize. PL measurement is not of one specific observable and discrete behaviours, but rather a combination of four domains: affective, physical, cognitive, and behavioural. To date, only the Canadian Assessment of Physical Literacy has been validated as an integrative assessment of PL (Longmuir et al., 2015). However, CAPL has only been
validated to assess children from 8 to 12 years old and has been criticized for not recognizing cultural differences, and for considering the four components as separate, providing a disproportional focus on physical competence (Edwards et al., 2018; Tremblay & Longmuir, 2017). CAPL has been revised, shortened, and theoretically aligned in its second version (Gunnell, Longmuir, Barnes, Belanger, & Tremblay, 2018; Gunnell, Longmuir, Woodruff, et al., 2018; Longmuir et al., 2018).

According to a tentative practical PL model for older adults (Jones et al., 2018) (Figure 2.2), PL is an emerging strategy to remodel the promotion of PA participation across the lifespan. By integrating five components: intrapersonal, interpersonal, organizational, community, and policy, the socio-ecological PL model would eventually become a meaningful resource for reducing older adults’ sedentary behaviours and successfully support the development of sustainable healthy lifestyle habits. In addition, the model provides a framework for strategic policy options and priorities that enable the right for all people to participate in meaningful PA across their life course (Almond, 2013; Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019; Chen & Sun, 2015). Despite a promising strategy, the model for older adults has not been tested at any level.
By emphasizing the focus not only on inter- and intrapersonal outcomes, but also on the organizational, community, and policy levels, interventions to develop PL to older adults seem promising. Although more research is needed to guide the best approaches to mitigate the barriers to perform PA and facilitate healthy, active aging. Innovative approaches into teaching and engaging older adults on new forms of physical activities, or relearning motor skills, would increase their repertoire of exercises and daily physical functioning.

### 2.2 The Use of Active Video Games as Physical Activity Tools

Exergames or Active Video Games (AVG) are popular terms used to describe video games that demand physical interaction between the player and the video game
system. AVG require the movement of the whole body to interact within a simulated environment. These tools can provide opportunities to perform PA and have been extensively studied in the past decades (Qian, McDonough, & Gao, 2020).

AVG have been recognized as a new approach to promote PA and health behaviours and is increasingly used in health promotion (Soltani, Figueiredo, & Vilas-Boas, 2020). As part of exercise programs, AVG have shown motor functioning improvements and positive attitudes towards PA (Chen et al., 2009; Clark & Kraemer, 2009; Gamberini, Barresi, Maier, & Scarpetta, 2008). Research has shown that interactive fitness and exergaming activities can support the development of PL (Sheehan & Katz, 2010).

Individuals who are more inclined to attempt to play AVG tend to be more likely to seek out sports or other leisure activities (Sheehan & Katz, 2010). Older adults who have had successful experiences in controlled virtual simulation environments often develop confidence when practicing PA (Yang et al., 2011). This confidence occurs regardless of how different it is when they get out in real environments. Exposing the individual to a variety of ‘real life’ activities that they have played electronically may be an unintended but welcome benefit from active video-gaming (Yang et al., 2011).

AVG have also been tested on young adult patients with chronic diseases such as stroke, shoulder pain, traumatic brain injury, Parkinson disease, heart failure, and obesity (Barry, Galna, & Rochester, 2014; Laver, George, Thomas, Deutsch, & Crotty, 2012; LeBlanc et al., 2013; Staiano, Abraham, & Calvert, 2013; Sveistrup et al., 2003; Verheijden Klompstra, Jaarsma, & Strömberg, 2014). Adverse effects have not been
reported in most of these studies, indicating that the equipment can be relatively safe to this populations (Morris, Louw, & Crous, 2010; Skjæret et al., 2016).

The study performed by Whyatt et al. (2015) demonstrated the effectiveness of structured AVG-based balance training and its role in fall prevention in older adults. The study was a randomized control trial, which included participants with low and high risk of falls. Forty individuals underwent five weeks of training and had their functional balance and confidence in balance assessed. The intervention included custom-made exercises, which was administered through a commercial VR hardware. The results showed significant improvement in balance on the intervention group compared to the control group. The authors concluded that the AVG exercises were perceived as immersive, and effective balance training for the elderly with risks of falls. An interesting result was the improvement in levels of reported balance confidence in the control group. Whyatt et al. (2015) raised a question: “Are people naturally inflating levels of perceived confidence by simply raising awareness of physical activity?”. Moreover, the authors indicated the need for specially designed AVG for the senior population that addresses its concerns and consider the cognitive and physical limitations of its members (Whyatt et al., 2015).

Multiple studies have reported improved functional balance, gait speed, muscle strength, and decreased fall risk after subjects underwent AVG-based exercise programs (Agmon, Perry, Phelan, Demiris, & Nguyen, 2011; Clark & Kraemer, 2009; Jungjin Kim, Son, Ko, & Yoon, 2013). Beaulieu et al. (2015) evaluated the effects of commercially AVG for exercise training. The pilot study was a multiple case series, which included three participants who underwent a 10-week supervised exercise using Microsoft Xbox Kinect. The participants improved their balance, lower limb strength, and overall satisfaction after
AVG intervention. The authors of this study considered that AVG were a safe home-based therapeutic tool. Although, authors’ interpretation on safety could be biased since the study was conducted in a supervised hospital setting and may not be applied to home-based unsupervised therapies. In addition, the findings cannot be generalized due to the small sample size and gender, since all participants were women (Beaulieu-Boire et al., 2015).

A systematic review of AVG training for older adults demonstrated that the innovative technology of AVG is effective in improving physical function although without consistent findings in specific functions such as balance control and gait speed. Forty-seven studies involving physical functioning training using AVG for adults aged over 65 years were included. The findings indicated limited evidence regarding the use of AVG-based exercise programs in particular to older adults with chronic diseases since most of the studies had selected healthy and community-dwelling participants (Skjæret et al., 2016).

Lund and Jessen (2014) analyzed the effects of AVG using modular interactive tiles. The quasi-experimental study involved eighteen community living older adults with ages ranging between 63 and 95 years recruited from community activity centers. The intervention comprised 12 weeks, of once a week sessions of 60-90 minutes under supervision. The outcomes measures were the Six-Minute Walk Test, the Chair-Stand Test, and the Timed up & Go Test and were assessed pre- and post intervention. The results showed a significant improvement in all outcome variables after the intervention and supported the authors to conclude that the AVG-based exercise is an effective therapeutic tool. This study was exploratory and did not provide inclusion and exclusion criteria,
resulting in selection bias, thus affecting the internal validity of the study and the external validity, such as generalizability.

A meta-analysis on the physical and cognitive impact of AVG in seniors included 36 studies (Zhang & Kaufman, 2016). The outcome measures included in this analysis were confidence, functional mobility, executive function, and processing speed. The authors stated that several studies reported multiple measures of the same outcome variable. In those cases, in which one measure was clearly better than the others, based on established validity, the best measure was used. In several studies, in which there was not a clear best measure, the authors used the average effect size. The results indicated significant improvements in all the outcomes after AVG training. The authors concluded that improvements in physical and cognitive functions were seen in both independent living and nursing home residents. Furthermore, most of the studies reported that video games were learned effectively by most older adults (Zhang & Kaufman, 2016). Previous studies involving AVG also showed greater enjoyment and increased confidence (Sveistrup, 2004). The studies also reported high adherence levels for participants in exergaming programs which shows the usability and user-friendly nature of this intervention (Konstantinidis et al., 2016; Nitz et al., 2010).

Chao et al. (2015) examined the difference in physical function, fear of falling, depression, and quality of life for assisted living facility residents who received exergame intervention and those who only received the health education program. The exergame group received the intervention twice a week for 4 weeks. The education group received health education material once a week. After the 4-week intervention, the exergame group
showed significant improvements in balance, mobility, and depression, while the education group showed no significant improvement in any of the outcomes.

Although commercial games have been tested in most studies, the development of customized AVG has not been extensively researched. For example, Wüest et al. (2014) performed research to test the usability of customized AVG. Thirteen participants completed a supervised 12-week AVG exercise program comprising three, thirty-minute sessions per week with a ten-minute break in each session. The outcome measures were the Technology Acceptance Model, Berg Balance Scale, Timed Up and Go, Force Platforms, and Short Physical Performance Battery. Results indicated that participants perceived AVG as useful for exercise training, and the authors reported no adverse events. The outcomes demonstrated improvement in balance and mobility. This study’s results should be analyzed carefully because of its small sample size, convenience sampling, and study design, putting the internal validity at risk of bias.

Researchers have also developed AVG platforms specifically for the elderly population (Nawaz et al., 2016). One study reported the usability of a custom AVG platform entitled Fit for All, which was tested in the elderly population in care centers (Konstantinidis et al., 2016). The platform used commercial hardware Wii remote controls with customized video games that provided online feedback to the players and adjusted intensity and difficulty levels. This study included 232 participants engaged in a two-month exercise program with a frequency of three days per week, with each session lasting sixty minutes. The control group was submitted to cognitive training for the same duration. The study reported high levels of usability and adherence with significant improvement in
most physical function components such as balance control, muscle strength, and endurance.

A qualitative study focused on developing and testing user-centred intervention considering the challenges of working specifically with elderly populations (Agmon et al., 2011). In this study, older adults played Nintendo Wii games mentioned challenges, with the application of this tool such as difficulty in navigation and the nature of the game for the elderly. In this study, seven participants attended a workshop and had the chance to play three customized Kinect-based games for 25 minutes. After completing the game protocol, participants’ feedback was audio recorded during a focus group session. Nawaz et al. (2014) recommended that a simple interface, less distraction, flexibility in difficulty level are required when designing specific AVG for the elderly population. The study presented useful recommendations for AVG designing, such as keeping simplified interfaces, limited and clear information on the screen, slow progress, and engaging music (Nawaz et al., 2014).

Other than efficacy in physical functions, researchers have explored AVG for their psychological effects on motivation, adherence, self-adherence and general well-being. A quasi-experimental study was performed in Singapore to compare the effects of Wii console on affect, self-esteem, loneliness and PA in residents of a nursing home. The participants were involved in a six-week Wii-games exercise program, which had three sessions each week. Each session’s duration was 1.5 hours, while the compared group played board games during this duration. The Wii group showed significant improvement in affect, self-esteem, and PA but significantly lower on loneliness than the board games
group. The results showed that playing AVG in group settings could be helpful to avoid the isolation, and the perception of loneliness (Jung, Li, Janissa, Gladys, & Lee, 2009).

Kahlbaugh et al. (2011) proposed using an AVG group compared to a control group that only watched television. After ten weeks of intervention, AVG participants reported higher positive moods and lower loneliness than controls. This study supported the use of more than one player to incorporate the effect of social interaction. The multiplayer and group sessions of AVG can provide interaction between seniors and their peers, expanding their social network. The seniors can enjoy this experience with their family members since video games are highly popular among younger generations.

A serious question posed to the AVG application in healthcare as a PA tool is the extension of its physiological effects. A meta-analysis conducted by Peng, Lin, and Course (2011) exploring the physiological effects of AVG in different age groups. It indicated that AVG produce significant increases in heart rate, oxygen consumption, and energy expenditure. The overall effects are similar to light-to-moderately intense PA and might be used for aerobic fitness improvements. This meta-analysis presents a limitation on its interpretation since 14 out of the 18 included studies were performed on children, and those results cannot be generalized to seniors (Peng et al., 2011). Similar results were found in other studies that categorized AVG as light-to-moderately intense PA. The authors recommended its use in order to induce PA in sedentary populations (Bailey & McInnis, 2011; Graves et al., 2010; Griffin, Shawis, Impson, Shanks, & Taylor, 2013). Thus, virtual reality presents the advantage of being physically engaging in terms of physiological effects, which might be compared to traditional forms of exercise.
2.2.1 Traditional and Active Video Game Interventions for Older Adults

Traditional PA programs usually include multisystem and multifactorial approaches of management and combines different exercises to enhance muscle strength, flexibility, endurance, agility in functional activities in a variety of environments (Griggs, 2015; Wallian & Chang, 2006). Recently, interactive virtual environments and AVG have also been employed to improve physical functioning in elderly populations (Gil-Gomez, Llorens, Alcaniz, & Colomer, 2011; Gil-Gomez, Lozano, Alcaniz, & Perez, 2009). The results suggest that AVG were a safe and effective alternative to traditional treatment to improve static balance.

Means et al. (2005) performed a randomized controlled study to analyze the effects of a multiple exercise program to see its effect on physical functioning on community-dwelling older adults. The participants attended a six-week supervised group exercise program, which included walking, stretching, strengthening, and balance exercises. There were three sessions each week, each session lasting for 90 minutes, including warm-up and cool down. The results showed significant improvement in functional abilities and decreased incidence of falls in a six-month follow-up compared to controls (Means et al., 2005).

A systematic review of fall prevention programs showed that exercise is an important component of such programs in elderly populations (Gardner, Robertson, & Campbell, 2000). The studies included in the review suggested that the exercise programs involving multiple interventions (patient education, reducing hazards in living place, dietary changes, and exercises, such as Tai Chi and dance along with traditional exercises)
were more effective in reducing falls as compared to programs using exercises exclusively (Gardner, Robertson, & Campbell, 2000).

Another systematic review aimed to analyze the effects of different exercises in elderly individuals found that the strengthening exercises, 3D exercises (tai chi, qi gong, dance), and multiple exercise programs had a significant impact. The review included 94 studies performed to verify the effect of different therapeutic exercises on balance and physical functioning in healthy community living older adults. The study also indicated that different active games address different motor skills demands. Thus, the authors concluded that an exercise program for older adults should include different types of games to maximize the efficiency of the intervention (Howe, Rochester, Neil, Skelton, & Ballinger, 2011).

Other recommended forms of exercise to develop functioning skills in later life include yoga, walking program, circuit training, and obstacle course (Kisner, Colby, & Borstad, 2017; Sherrington et al., 2008). Evidence on the literature has demonstrated that carefully-designed exercise programs can improve physical functioning in older adults and subsequent reductions in the number of falls (Cadore, Rodríguez-Mañas, Sinclair, & Izquierdo, 2013; Osugi, Iwamoto, Yamazaki, & Takakuwa, 2014; Sturnieks, St George, & Lord, 2008). The traditional methods of exercise therapy seem effective but are often considered monotonous and boring, leading to lack of motivation, engagement, and adherence to exercise programs by older adults (Fang et al., 2020). Thus, based on aforementioned evidence, effectiveness of AVG exercise programs for older adults including physical-psycho-social approach may enhance the four domains of PL among the elderly.
Chapter Three: Using Active Video Games to Improve Older Adults’ Physical Literacy: A Theoretical Approach

3.1 Abstract

Physical literacy (PL) is considered the foundation for lifelong engagement in physical activity (PA). Despite evidence of the positive effects of PA in the prevention of disease, the prevalence of sedentary lifestyles continues to rise. A sedentary lifestyle may influence the capacity to perform activities that are needed to maintain physical independence in daily living and delay age-related functional declines. In this context, active video games (AVG) are innovative tools to increase the level of PA, taking advantage of the dynamic challenges in a fun environment. AVG are promising tools that could allow older adults to develop, maintain, and recover their PL. However, little is known regarding their potential as a valuable tool in the development or recovery of PL domains by older adults. In this paper, a theoretical framework is presented to explore the ideas of using AVG to improve older adults’ PL.

*Keywords*: Physical Activity; Aging; Exergame; Virtual Rehabilitation; Seniors; Elderly.

3.2 Introduction

As the global senior population increases its numbers year-by-year, reports on age-related chronic diseases and functional limitations grow proportionally (Dogra, Clarke, & Copeland, 2017). The relationship between the factors that impact healthy aging processes, including quality of life (QOL) and physical activity (PA) behaviour, has been increasingly discussed in the literature (Hoeger, Hoeger, Hoeger, & Fawson, 2018). The physical and
psychosocial benefits of practicing PA are well-established (Warburton, Nicol, & Bredin, 2006). Despite evidence of these positive effects, the prevalence of sedentary lifestyles continues to rise (Althoff, Hicks, King, Delp, & Leskovec, 2017).

Regular PA engagement is a key factor in preventing several health risks that affect older adults, such as age-related physical and cognitive functional impairments (Engeroff et al., 2019). Addressing positive changes in lifestyle behaviours, including the addition of physical exercise in daily routines, significantly reduces the risk of chronic diseases and mortality rates (Freiberger et al., 2018). In addition to the availability of validated PA guidelines, creating the infrastructure and culture to support greater accessibility can facilitate PA engagement by older adults. This includes reducing or removing perceived barriers that impede the enrollment and the acquisition of resources, such as the lack of motivation and confidence in performing PA and possible financial limitations, such as the cost to traveling to the training facility (Hui & Rubenstein, 2006).

The use of technologies to engage in PA may help older adults to overcome their age-related barriers. With the increasing trend towards the emerging technologies for improving health and fitness practices, research has also made great strides in understanding the potential and pitfalls of these technologies. Innovative approaches for PA promotion currently being explored by researchers and health practitioners include smartphones (Feter, dos Santos, Caputo, & da Silva, 2019), wearables and fitness trackers (Brickwood, Watson, O'Brien, & Williams, 2019), and virtual reality (VR)-based exercises, such as active video games (AVG) (George, Rohr, & Byrne, 2016; Sheehan & Katz, 2010).
In particular, AVG focus on the interaction of the player immersed in a virtual environment (VE) performing PA in a structured manner. This innovative technology has the potential to be effective tools to prevent long-term sedentary leisure time and enhance individuals’ competence, motivation, and confidence to perform PA (Yasobant, 2016). AVG are relatively inexpensive and, despite some controversy on the need of supervision, when used appropriately they can be safely used in the place of residence (Campelo & Katz, 2018; Morrison, Simmons, Colberg, Parson, & Vinik, 2018).

AVG have been used for recreational and social interaction purposes (Hausknecht, Schell, Zhang, & Kaufman, 2015), research (Hiraga, Tonello, & Pellegrini, 2017), and rehabilitation tools as an integrated part of clinical practice (Griffiths, Kuss, & de Gortari, 2017; Sheehan & Katz, 2010). However, the implementation of AVG systems in exercise programs needs to be grounded in theory informed by a clear scientific rationale. An appropriate theoretical framework to sustain effective implementation of such tools may optimize research impact and strengthen healthcare policies, and ultimately facilitate a more active lifestyle for older adults.

Through the establishment of a holistic approach towards healthy and active aging, physical literacy (PL) has emerged as a promising strategy to increase lifelong PA participation for all ages. PL is defined by the International Physical Literacy Association (IPLA, 2015, p. 1) as “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life”. Based on this theoretical framework, offering opportunities for the senior population to become healthier and more active would address a complex interplay of personal and structural changes. Personal factors include motor and cognitive functions, personal
beliefs, attitudes, and behaviours, while structural factors include environmental, social and cultural contexts, and public health policies.

The PL concept holds promise as a realistic strategy to promote regular PA engagement. However, there still is relatively little evidence to support the use of PL concepts for older adults’ achievement of recommended PA levels and health-related QOL. The purpose of this conceptual paper is to provide a theoretical approach to the use of AVG to improve older adults’ PL.

### 3.3 Literature Search Strategy

Four electronic databases (PubMed, SPORTDiscus, Cochrane Central Register of Controlled Trials, and Web of Science Core Collection) were searched for articles published from their inceptions to January 2020. Keywords were searched based on the participants (older adults, seniors, and elderly), exposure (exergames and active video games), and outcomes (motivation, confidence, physical competence, knowledge, understanding, behaviour). Reference lists of included studies were also searched for relevant articles.

### 3.4 Fundamentals of Physical Literacy

The concept of PL has been used in scientific literature since the late 1930s (Roetert, Kriellaars, Ellenbecker, & Richardson, 2017). However, it has become more widely used in the last few decades, mainly guiding children’s physical education programs and sports skills development. Through philosophical debates, the PL framework has emerged to mitigate the general population’s decline in PA engagement. Margaret Whitehead has spearheaded the discussion regarding the significant value of PA through her monist, existentialist, and phenomenological perspectives of the human body and its
interaction with the environment. Whitehead (2004) summarized this understanding by stating that PL is not a skill or ability, “but a disposition to use experience, understanding, and abilities to interact effectively with the world” (Whitehead, 2004, pp. 4).

Integrating a variety of motor capacities into a long-term development partly characterizes how individuals are physically literate (Edwards, Bryant, Keegan, Morgan, & Jones, 2017). From birth to death, individuals develop a variety of skills to move and learn about the world and themselves through movement. As individuals have different interactions and experiences, the ways they interpret these interactions and develop their capacities are unique and personal. Individual experiences and unique contexts explain why individuals begin to walk at different ages, learn some activities more easily than others, and present varying levels of self-esteem. Thus, PL is important not only for engaging in PA or “being fit”, but also as part of one's “life foundation” for overall health and well-being across the lifespan (Durden-Myers, Green, & Whitehead, 2018).

PL is the foundation for an active lifestyle and is a life-long journey (Edwards et al., 2017). A life-course approach to human development acknowledges that there are critical periods during the lifespan when motor skills, daily habits, coping strategies, attitudes, and personal values are developed. There are also life transitions when developmental opportunities can be disrupted and therefore alter life course trajectories and future health. Developing PL and engaging in PA programs can enable older adults to develop self-confidence, build physical competency, and improve interpersonal relationships. Thus, optimizing PL development and identifying the domains that are lacking may result in increased PA adoption.
The literature provides consensus on several common attributes when defining the concept of PL, including four main domains (IPLA, 2015, p. 2):

“Affective - Motivation and confidence: Motivation and confidence refer to an individual’s enthusiasm for, enjoyment of, and self-assurance in adopting PA as an integral part of life.

Physical – Physical competence: Physical competence refers to an individual’s ability to develop movement skills and patterns, and the capacity to experience a variety of movement intensities and durations. Enhanced physical competence enables an individual to participate in a wide range of physical activities and settings.

Cognitive – Knowledge and understanding: Knowledge and understanding include the ability to identify and express the essential qualities that influence movement, understand the health benefits of an active lifestyle, and appreciate appropriate safety features associated with PA in a variety of settings and physical environments.

Behavioural – Engagement in physical activities for life: Engagement in physical activities for life refers to an individual taking personal responsibility for physical literacy by freely choosing to be active regularly. This engagement involves prioritizing and sustaining involvement in a range of meaningful and personally challenging activities, as an integral part of one’s lifestyle.”
Despite the well-established PL domains, Whitehead (2010a) stated that longitudinal studies are essential to understanding how individual and environmental factors interact, including the interactions happening in each stage of the PL journey and, in particular, how the later stages of this journey, as older adults, are impacted by the preceding phases. According to Whitehead (2010a, pp. 14, 15) relationship between domains are best described in two stages: “Motivation, confidence and physical competence, and effective interaction with the environment are the three attributes that form the kernel of the concept and are mutually reinforcing . . . Motivation can encourage participation and this involvement can enhance confidence and physical competence. The development of this confidence and competence can in turn maintain or increase motivation. Development of confidence and physical competence can facilitate fluent interaction with a wide range of environments. This effective relationship with the environment, with the new challenges this presents, can in turn enhance confidence and physical competence. The success of developing effective relationships with a range of environments can add to motivation. This enhanced motivation can in turn encourage exploration and promote effective interaction with the environment . . . As individuals have rewarding experiences in physical activity they can experience a positive sense of self and enhanced global self-confidence. In addition, awareness of the embodied dimension alongside a sound self-esteem will promote fluent self-expression and perceptive and empathetic interaction with others. Knowledge and understanding will be enriched by all aspects of participation.”

Researchers who have advocated for the application of the PL concept to older adults have defended the idea that the development of fundamental movement skills in
later life would be combined with the maintenance or retraining of functional movement skills that assist activities of daily living (Jones & Stathokostas, 2016). This recommendation corroborates other research that investigated perceptions of health and physical function concerning QOL and social engagement (Tkatch et al., 2017). Therefore, applications of PL concepts to older adults would focus on lifelong PA values, current biopsychosocial conditions, and the relationship to healthcare savings as a result of PA behaviour change, chronic disease prevention, and injury risk reduction.

A socio-ecological PL model for older adults was recently developed as a strategy for PA advocates, healthcare providers, and facilitators to support PA guidelines (Jones et al., 2018). Jones et al. (2018) suggested that a PL model for older adults provides a new and effective strategy to target promotion and adherence of PA for the general senior population. The adapted PL model for older adults introduces four domains - interpersonal, organizational, community, and policy - in order to understand both PA participation and the quality of the PA experience. Sub-domains within each domain and the interactions between them indicate how the older adult perceives PL. Understanding each domain and its elements could facilitate a new and practical framework to specifically target PA promotion, compliance, and health outcomes for older adults.

3.5 Virtual Reality Exercise Games

Current biopsychosocial trends in healthcare have demonstrated the challenges for overarching community- and home-based health management systems (Gandarillas & Goswami, 2018). Developing effective strategies to promote increased amounts of PA for older adults is one of the challenges for traditional healthcare systems (Sansano-Nadal et al., 2019). In general, PA programs designed for older adults aim to encourage
maintenance of an active daily routine; however, low adherence rates have been reported (Picorelli, Pereira, Pereira, Felício, & Sherrington, 2014). The main reasons for non-adherence include socioeconomic status, marital status, musculoskeletal and cognitive status, and presence of chronic conditions, such as osteoarthritis and depressive symptoms (Rivera-Torres, Fahey, & Rivera, 2019). Furthermore, traditional PA programs for older adults remain costly and present limited effectiveness (Gandarillas & Goswami, 2018).

Alternative programs targeting older adults to engage in PA practices are needed, especially for those who do not have previous physical exercise experiences and do not feel motivated to begin and maintain regular practice. However, the upsurge in demand for innovative healthcare tools must be balanced with a credible evidence base and guidance for suitable use by healthcare providers (Gandarillas & Goswami, 2018). The inclusion of alternative methods to traditional approaches, such as the use of VR-based exercises in traditional PA programs, presents the potential to increase its accessibility, effectiveness, and reduce costs (Dascal et al., 2017).

VR can be described as a simulation of real-world environments through a computer-based scenario and experienced through a human-machine interface (Holden, 2005). The VEs are “interactive, virtual image displays enhanced by special processing and by nonvisual display modalities, such as auditory and haptic to convince users that they are immersed in a synthetic space” (Stephen, 1994, p. 17). There are three key aspects linked to VR systems: level of immersion, visual realism, and interaction. VR systems create a two- or three-dimensional environment, in the form of visual graphics, where the users are engaged. While the users interact with this VE, their movements are captured by sensors, allowing the system to provide feedback on their performance.
A range of companies have produced commercial VR devices enhanced with gamification features, called exergames or active video games (AVG). AVG have been investigated to promote healthier aging, prevent risk of injuries and chronic diseases, and recover physical and cognitive functions (Halton, 2008). Campelo, Hashim, Weisberg, and Katz (2017) addressed four main components to consider when using AVG as an exercise tool: recipients and providers, applications, social factors, and VEs (Figure 3.1).

Recipients are the target individuals of the intervention process. Providers include professionals such as personal trainers, physiotherapists, psychologists, physicians, recreation therapists, researchers, and other healthcare providers, who present knowledge translation strategies to implementing recipient-oriented PA programs. Perez-Marcos, Bieler-Aeschlimann, and Serino (2018) showed that AVG is feasible for a wide range of

---

**Figure 3.1 Main factors to consider when using AVG as an exercise tool (Campelo et al, 2017, permission was granted to use figure); Note: VR = Virtual Reality; 3D = three-dimension.**
applications, from entertainment purposes to the treatment of health conditions, such as pathological physical, cognitive, and psychological conditions.

According to Levac, Glegg, Colquhoun, Miller, and Noubary (2017), approximately 50% of healthcare providers with clinical experience have used AVG in their treatments; however, from this total, only 12% of providers used AVG on a regular basis. The frequency of use ranged from less than once per month (46% of respondents) to monthly (28%), weekly (22%), and daily (4%) (Levac et al., 2017). The most frequently reported scenarios for AVG-based therapy were stroke (25.8%), brain injury (15.3%), orthopedic/musculoskeletal diagnoses (14.9%), and cerebral palsy (10.5%). The top functional areas for which AVG was used were balance training (39.3%), exercise/PA (19.8%), and mobility/gait (12.1%) (Levac et al., 2017).

Interaction in a VE is the recipient's physical involvement within the system. The type of interaction between the recipients and the VEs is a critical component for successful program implementation. Three key aspects of VE must be considered: a safety protocol, an interface that connects the recipients within the environment, and matching the activities to the specific function being restored. Realistic VEs that enhance the sense of “being present” in VR are key components to optimizing the user experience (Campelo & Katz, 2018; Vignais, Kulpa, Brault, Presse, & Bideau, 2015).

The sense of presence in VR is intimately related to the level of immersion presented by each device. There are many commercially available VR systems, including simple 2D graphics devices, fully immersive 3D/360-degree CAVE systems, head mounted displays, and haptic interfaces. Stimuli are most often visual and audio based. The feedback provided by each system in regard to the movements performed in the real world
needs to be synchronized, otherwise motion sickness, which in VR is called cyber sickness, can be induced (Faisal, 2017; Vignais et al., 2015). Thus, choosing the proper VE by the providers relies on the capacity of the specific VR system to create controllable, interactive, multisensory environments to offer meaningful clinical assessment and user-oriented interventions (Campelo et al., 2017; Weisberg, Campelo, Bhaidani, & Katz, 2020).

AVG has received increasing attention due to its potential therapeutic benefits and opportunity for mitigating PA barriers (Halton, 2008). Community recreation centers and healthcare facilities have taken the first steps towards creative and innovative strategies to offer AVG-based exercise programs (Glueckauf & Noël, 2011). Implementation in supervised settings have employed commercial AVG, which are not specifically designed for older adults. The unsupervised use of AVG by older adults in their own home is still under investigation and may be feasible for those without major mobility or cognitive impairment, thereby accommodating PA barriers, such as traveling to healthcare facilities (Garcia et al., 2016; van Diest et al., 2016).

AVG do not replace the clinical expertise and human factors, but rather provide alternative supports to empower older adults to participate in their own well-being. The complexity of this emerging healthcare area is still underestimated and a variety of adaptations to commercially available devices is needed in order to achieve individualized outcomes. Additional factors to consider during the creation and implementation of an AVG program are the accessibility to technology, commercial versus customized solutions, cost, cultural sensitivity, attitudes and behaviours of the recipients, and the providers’ expertise.
Despite AVG’ potential to help individuals engage in PA, little is known about the effects on PL development and its progress. An ecological model considering personal and structural factors would be helpful to understanding how the strategies for AVG implementation on exercise programs will affect PL outcomes. In order to explore the ideas of improving older adults PL through AVG, it is necessary to understand the effects of each strategy on each of the four PL domains. Optimizing PL in each of four domains may ultimately enhance overall benefits of PA.

Successful implementation of AVG to improve PL would depend on contextual understanding of personal and structural levels. Personal goals would focus on optimizing each of PL domains in order to maintain or improve overall functioning, maximize social interaction, and minimize the risk of injuries and chronic diseases in older adults. Structural factors, such as PA programs, resources, and services would offer personally meaningful, culturally relevant, and accessible opportunities for PA participation. It is important to consider that there is a wide context variation in personal and structural factors, strategies, locations, and type of AVG devices as described in Figure 3.2.
3.6 An Ecological Approach to Use Active Video Games to Optimize Physical Literacy

According to Craig (2013), the application of AVG could be guided by key concepts from ecological psychology, which proposes a “direct” integration of perception and action. In this theoretical rationale, perception and action have a direct and cyclical relationship to PA engagement (Davis & Burton, 1991; Stone, Strafford, North, Toner, & Davids, 2019). In its turn, AVG could help older adults to become attuned to rich
information in a simulated environment, thereby allowing possibilities of motor action. This central theoretical principle informs the design of AVG to facilitate the exploration of relationships between perception and action emerging during interactions with a variety of environments. Understanding what perceptual information is used to guide action is very important when considering older adults' cultural differences.

Research in different cultural environments has focused on the interaction between culture, technology, acceptance, and adoption (Huang, Teo, Sánchez-Prieto, García-Peñaño, & Olmos-Miguelández, 2019). According to the policy framework published by the WHO (2002), culture is a cross-cutting determinant for understanding active aging. Policies related to PL development need to consider current cultures and traditions while de-bunking outdated stereotypes and misinformation, and proactively design programs that are culturally sensitive.

There are critical universal values that transcend culture. PL is described as a universal concept in which everyone benefits from its development. However, its specific expression will depend on each individual’s endowments with respect to the four PL domains, and will be particular to the culture in which one lives (Whitehead, 2010b). There will be different challenges and opportunities in every culture, both in respect to the demands of everyday living and in relation to culturally recognized forms of structured PA.

Different social interaction patterns have been found when comparing interventions with seniors from different cultures under the same conditions (Baez, García, & Ibanez, 2016; Nikitina, Didino, Baez, & Casati, 2018). Al-Gahtani, Hubona, and Wang (2007) studied the effect of cultural differences on an individuals' use of technology in which cultural values, such as collective achievements and interpersonal relationships played a
significant role in technology readiness. Results consistently showed the feasibility of using technology to promote PA, providing further insights into the effects of the various design choices, and the limitations to promoting social participation. Consideration about cultural differences may inform AVG designers to enable and stimulate social interactions between users (Barbosa Neves, Franz, Judges, Beermann, & Baecker, 2019).

The investigation of which physical, psychological, and social determinants influence well-being and how past experiences might help support or impede PL are important steps to understanding the relationships between PL and AVG applications in healthcare. According to Saposnik et al. (2016), AVG can be safe and particularly suitable for older adults to participate and benefit from the health effects of leisure and fitness activities. Moreover, research exploring the impact of AVG use by older adults shows positive improvements in PA levels and a reduction in sedentary behaviours during leisure time (Kari, 2017). Further benefits of AVG-use include focusing players’ attention (Hwang, Hong, Jong, Lee, & Chang, 2009), increased gameplay engagement (Belchior, Marsiske, Sisco, Yam, & Mann, 2012), improvement in range of motion (Bobeth, Schmehl, Kruijff, Deutsch, & Tscheligi, 2012), increased mental stimulation (Marston & Smith, 2013), and feelings of social connectedness in their peer groups (Meekes & Stanmore, 2017; Pedell, Vetere, Kulik, Ozanne, & Gruner, 2010). Thus, four main factors are theoretically involved in establishing the relationships between the PL concept and the implementation of AVG in healthcare: Cognitive, Affective, Behavioural, and Physical (Table 3.1).
Table 3.1. The relationship between the physical literacy concept and the implementation of AVG in healthcare.

<table>
<thead>
<tr>
<th>PHYSICAL LITERACY</th>
<th>FACTORS</th>
<th>AVG IMPLEMENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge &amp; Understanding</strong></td>
<td>Cognitive</td>
<td>Virtual Environments</td>
</tr>
<tr>
<td>• Ability to identify essential qualities that influence movement</td>
<td></td>
<td>• Reactivation of cortex areas by boosting the neuroplasticity processes</td>
</tr>
<tr>
<td>• Understand the health benefits of an active lifestyle</td>
<td></td>
<td>• Goal-oriented tasks in VR matching specific function being restored</td>
</tr>
<tr>
<td>• Understand the safety features of proper movement</td>
<td></td>
<td>• Perceptive-motor feedback</td>
</tr>
<tr>
<td><strong>Motivation &amp; Confidence</strong></td>
<td>Affective</td>
<td>Recipients and Providers</td>
</tr>
<tr>
<td>• Enthusiasm</td>
<td></td>
<td>• Adequate communication</td>
</tr>
<tr>
<td>• Enjoyment</td>
<td></td>
<td>• Cooperation between patients and healthcare professionals</td>
</tr>
<tr>
<td>• Self-Assurance</td>
<td></td>
<td>• Respect for cultural values and individual patients needs</td>
</tr>
<tr>
<td><strong>Daily Behaviour</strong></td>
<td>Behavioural</td>
<td>Social Factors</td>
</tr>
<tr>
<td>• Taking personal responsibility to engage in PA</td>
<td></td>
<td>• Multiplayer interface that connects the recipients within the environment</td>
</tr>
<tr>
<td>• Freely choosing to be active on a regular basis</td>
<td></td>
<td>• Exposure to cooperative and competitive activities</td>
</tr>
<tr>
<td>• Prioritizing and sustaining PA engagement</td>
<td></td>
<td>• Reproduction of activities of daily living and social interactions</td>
</tr>
<tr>
<td><strong>Competence</strong></td>
<td>Physical</td>
<td>Applications in Healthcare</td>
</tr>
<tr>
<td>• Motor functionality</td>
<td></td>
<td>• Efficient treatment of biopsychosocial disorders</td>
</tr>
<tr>
<td>• Ability to learn, develop, and control motor skills</td>
<td></td>
<td>• Enhanced gait speed, balance control, and walking skills</td>
</tr>
<tr>
<td>• Capacity to exercise in a wide range of environments</td>
<td></td>
<td>• Increased range of motion of upper and lower limbs</td>
</tr>
</tbody>
</table>

Note: VR = Virtual Reality; PA = Physical Activity.
3.7 The Interrelated Cognitive Factors

During the aging process, cognitive functions gradually present a decline in neurological processing speed, memory, attention, and executive functioning (Harada, Love, & Triebel, 2013). Given the high burden imposed on the healthcare system and QOL, a search for effective interventions to slow or prevent cognitive decline and improve cognitive functions is of great significance. Epidemiological research has suggested that a lifestyle combining tasks that stimulate physical and psychosocial functions has beneficial influences on cognitive performance (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Groot et al., 2016).

Evidence that the regular PA practice prevents the acceleration of age-related cognitive decline and improves cognitive function across the lifespan has been established (Crevier-Quintin, 2017). Researchers have demonstrated that cognitively demanding regular exercise, including the implementation of AVG-based programs, has a more significant impact on cognitive function than more simple exercises (e.g., walking) (Diamond, 2015; Tait, Duckham, Milte, Main, & Daly, 2017). Dos Santos Mendes et al. (2012) showed that the use of AVG as a leisure activity resulted in increased PA engagement while learning new skills. A recent meta-analysis of 15 studies with older adults indicated that using AVG showed medium-size positive effects on general cognitive function (Stanmore, Stubbs, Vancampfort, de Bruin, & Firth, 2017). Additionally, the meta-analysis by Wang et al. (2016) found that AVG training served as a useful tool for cognitive improvement. These studies supported the presence of brain plasticity from seniors’ neural system, which enables them to develop new motor and cognitive skills or restore declined capabilities (Cai, Chan, Yan, & Peng, 2014; Wu, Chan, & Yan, 2016).
A central perspective underpinning PL is the existentialism theory (Whitehead, 2001). The basic premise of existentialism is that individuals “create” themselves by interacting with the surrounding environment (Whitehead, 2001). Davids, Williams, and Williams (2005) suggested that, when planning a motor action, the cognitive processes use previous knowledge and experiences to search for relevant sources of information, anticipate time-constrained events, and adapt to information sources that the perceptual systems receive from the environment. While interacting with the environment, cognitive representations, such as spatial and temporal information, memories, thoughts, feelings, and images are used as possibilities for motor actions, called affordances (Gibson, 1979). Since AVG present interactive “virtual” affordances consistent with “real” environments, users can select the type of VE and the level of game difficulty to perform one or more motor actions. These virtual affordances would aide in creating new perspectives and potential adoption of new behaviours.

Due to the accumulation of information based on life experiences, healthy older adults tend to retain more knowledge compared to younger adults. Accumulating knowledge is considered a “crystallized ability” and remains stable or even gradually improves through decades of life (McDonough & Allen, 2019). Social cognitive theories advocate that knowing about the benefits of technology-based PA increases intentions to adopt innovative systems and move forward in the process of health behaviour change (Seah et al., 2019). However, research is still needed to determine the key factors that contribute to the knowledge-behaviour relationship. Thus, studies should be undertaken to identify the most effective type of AVG and the ideal dose-response to provide a more
nuanced cognitive approach to people's knowledge of PA benefits and adoptions of health behaviours.

### 3.8 The Interrelated Affective and Behavioural Factors

Investigating PL within a multi-theoretical approach increases the predictive strength of PA behaviour determinants and facilitates the design and implementation of effective AVG-based interventions for older adults. For example, a multi-disciplinary review of technology use by older adults employed the social cognitive theory perspective to analyze the literature. The findings indicated that the triangulation of environmental, affective, and behavioural factors contributed to adaptability, usability, and acceptance of technology (Wagner, Hassanein, & Head, 2010). In addition, Spence and Lee (2003) suggested that socio-ecological models of health behaviour were useful to understanding individuals' attitudes towards PA engagement.

Research has indicated that when designing PA interventions for older adults, it is important to understand not only attitudes but motivations to engage in PA (Rasinaho, Hirvensalo, Leinonen, Lintunen, & Rantanen, 2007). Motivation is one of the most important psychological drivers of human behaviour (Cerasoli, Nicklin, & Ford, 2014). According to self-determination theory, there are two types of motivation critical for sustained behavioural change: intrinsic (the internal desire to do an activity) and extrinsic (dependent on a reward received whenever an activity is completed) (Ryan & Deci, 2017). The use of extrinsic motivation in PA interventions can serve to establish a new behaviour, but over time, the individual needs to see the intrinsic value in order to maintain the behaviour (Dacey, Baltzell, & Zaichkowsky, 2008).
Chou (2015) organized motivating factors into eight components: meaning, empowerment, social influence, unpredictability, avoidance, scarcity, ownership, and accomplishment. AVG must appeal to one or more of these motivational drivers in order to keep users engaged over time (Laut, Cappa, Nov, & Porfiri, 2015). In order to ensure sustainable behavioural change without relapse, AVG must go beyond simple achievements and points. Recipients must be able to self-identify with goals that are meaningful to them as this will help them accept the intrinsic value of the task resulting in more autonomous, internalized behaviours. Kappen, Nacke, Gerling, and Tsotsos (2016) showed that the motivational aspects of AVG positively related to exercise engagement are due to purposeful interactions, customization of activities, fostering independence, building relationships, sharing, and accommodating preferences that relate to seniors’ lifestyle attitudes.

In general, AVG has been found to have a therapeutic value due to the affective factors of self-efficacy, satisfaction, well-being, and social integration (Loos, 2017; Pasqualotti, Amaro, & Neves, 2019). Pasqualotti et al. (2019) investigated the motivation to play AVG and the perceptions of the experience of playing such games. The study indicated that older adults who participated in an AVG-based exercise program felt “technologically included,” which seemed to positively affect their perceived self-efficacy toward new technologies, emotional state, and social perceptions of themselves (Pasqualotti et al., 2019). Expressions of joy and curiosity are expected when participants feel they have enough skills to independently handle the equipment (Pasqualotti et al., 2019).
Emotional stability and social interaction seem to facilitate the adoption of AVG-use and could have positive effects on older adults’ well-being (Loos, 2017). When playing in group sessions, AVG allow interpersonal connectedness, which is associated with several social and health benefits such as satisfaction with life, social inclusion, and general well-being (Cornwell & Waite, 2009; Park & Bischof, 2013). Additionally, Lin, Lee, Lally, and Coughlin (2018) demonstrated that participants who were provided with VR experiences reported the following changes: improved overall perceived health and social well-being, decreased experiences of negative emotions, reduced perception of being isolated, less likely to show signs of depression, and increased feeling of better handling stress. After the intervention, participants had indicated that they were satisfied with the experience and were more likely to use and recommend VR systems to their peers (Lin et al., 2018).

With the ability to make its users feel more engaged in PA, VR has the potential to increase self-confidence and change sedentary behaviours (Gao & Lee, 2017). Evidence has indicated that the body’s interaction with VE features adds to the confidence and ability to practice PA (Ellmers, Young, & Paraskevopoulos, 2017). However, individuals who have experienced fear of falling or had decreased confidence in their capability to complete a specific task without falling were more likely to avoid engagement in activities of daily living (Fong, Moua, DeNola, & Franklin, 2019; Schepens, Sen, Painter, & Murphy, 2012; Tinetti & Powell, 1993).

In recent years, the use of AVG has been a popular approach to increase confidence levels and reduce fear of falls (Stanmore et al., 2018; Taylor, Kerse, Frakking, & Maddison, 2018). A systematic review of the perceptions of AVG’ efficacy and fall
prevention suggested that AVG facilitate intrinsic factors such as the perceived need for safety (Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014). In addition, the findings suggested that the games’ difficulty levels selected for each person’s abilities were determinants to create challenging tasks and increase levels of confidence.

3.9 The Interrelated Physical Factors

Developing and maintaining physical functions are crucial factors for effective healthy and active aging. Accordingly, a physically literate person is expected to demonstrate the ability to move with poise and competence in multiple environments (Mandigo, Francis, Lodewyk, & Lopez, 2009). Research has demonstrated that despite being generally slower, older adults are as capable as young adults in developing new motor skills (Verwey, Abrahamse, Ruitenberg, Jiménez, & de Kleine, 2011). However, advanced motor skill performance, especially in sports, requires intense practice from a younger age, suggesting that it is more challenging to acquire such skills later in life.

The unprecedented growth of the aging population has increased focus on the importance of physical competence to maintain independent living and, specifically, to delay or prevent frailty and disability. Within a sedentary older adult population, the primary interest may not be the competence level of skills such as kicking or throwing, but rather the maintenance or re-training of foundational functional skills. Overall, the vast majority of VRehab-related studies have demonstrated promising results for enhancing general physical functioning. Many studies have shown that VRehab can provide similar to real-world effects in intensity and repetition (Dvorkin, Shahar, & Weiss, 2006; Viau, Feldman, McFadyen, & Levin, 2004). By engaging in AVG-based exercise programs,
older adults may be able to increase their physical competence, thereby improving their QOL (Berra, 2006).

Older adults can maintain and improve their cardiovascular and musculoskeletal functions by engaging in traditional PA programs (Warburton et al., 2006). Light PA is associated with improved function and a reduction in mortality rates of 30% in older adults (Manini et al., 2006). However, barriers to PA engagement, including reduced muscle strength and mobility limitations associated with advancing age, may reduce the energy expended when engaging in AVG-based exercises (Nolan, Nitz, Choy, & Illing, 2010). There is insufficient evidence to determine whether the use of AVG can provide enough intensity to meet the recommended cardiorespiratory fitness levels in the elderly.

The metabolic equivalent of task (MET) score is a validated physiological measurement to assess PA energy expenditure (Ainsworth et al., 2000). Validated PA guidelines for older adults recommend exercise intensity levels higher than 3 METs (Gault & Willems, 2017). Taylor et al. (2012) sought to quantify the energy cost of AVG play in older adults and to determine whether balance status affected gameplay energy expenditure (EE). Results indicated that the average EE during AVG-based exercises performed by twenty older adults was 2.27 METs compared to 0.98 METs when resting. AVG-based exercises may also provide benefits such as anaerobic power and muscle mass gain necessary for improved physical performance (Maillot, Perrot, & Hartley, 2012). Given these factors, AVG could be used to promote moderate EE in older adults, similar to light-to-moderate intensity exercise.

VR training has been widely used in rehabilitation therapy for physical impairments. Research has shown that when clinical patients engage in AVG-based
exercises, the prefrontal and parietal cortical areas and other motor cortical networks were activated (Mao, Chen, Li, & Huang, 2014). These activations may be involved in the neuroplasticity process responsible for the reconstruction or reorganization of neurons in the cerebral cortex (Viau et al., 2004). The findings also suggested that AVG training improves the spatial orientation capacity of older adults, thus facilitating the cortex to control postural balance and increase motion function.

Research has demonstrated that approximately 33% of people with chronic physical impairments have an increased risk of falling in their daily lives (Colledge, 2002). Moreover, the cause of more than 50% of older adults' accidental deaths are significantly correlated with falling and balance disorders (Agrawal, Carey, Della Santina, Schubert, & Minor, 2009). In fact, balance disorders are one of the leading causes of impaired mobility and compromised postural control in community-dwelling older adults (Pinter et al., 2018). Such impairments can also influence simple activities in daily life, such as walking.

Balance intervention programs that utilize AVG have demonstrated more significant improvement in functional balance when compared to no balance training (Mao et al., 2014). According to Mao et al. (2014, p. 1629), “... the simulated real-world scenarios give balance dysfunction patients more relevant information input than the real world to help them relearn their coordination and sense of balance.” The fidelity of the VE resemblance plays a vital role in the effectiveness of recruiting neural networks and the delivery of desirable outcomes at the functional level (Mao et al., 2014).

3.10 Future Directions

This conceptual paper highlights the rationale of implementing AVG-based exercise programs to improve older adults’ PL. Different needs between healthy and
clinical populations of older adults should be considered before generalizing 
implementation of AVG-based exercise into conventional physical training programs. For 
instance, studies that have included older patients' physical rehabilitative outcomes such as 
cancer, extremity limitations and amputation, lupus, spinal injuries, and hospitalized 
conditions, presented more significant effects of AVG play when compared to healthy 
peers (Staiano & Flynn, 2014; Zeng, Pope, Lee, & Gao, 2017). Future work could 
elucidate the boundaries surrounding AVG effectiveness in clinical and healthy older adult 
populations.

Several guidelines for PA in older adults have been validated (ACSM, 2009; Piercy 
et al., 2018; WHO, 2010). These specific guidelines highlight that the practice of regular 
physical exercise is not only aimed to already active older adults, but particularly 
imperative for those with chronic diseases and functional impairments. Commonly, these 
guidelines establish the minimum standard of >150min/week of moderate intensity 
activity. However, older adults who cannot meet the recommended amount or intensity of 
exercise can still benefit from lower engagement than those endorsed (Nelson et al., 2007; 
Piercy et al., 2018; Sparling, Howard, Dunstan, & Owen, 2015; WHO, 2010). AVG may 
help older adults meet the recommended amount of daily PA, especially those that are 
starting with an activity program.

Before initiating physical exercise practice, older adults should undergo pre-
exercise assessments (Elsawy & Higgins, 2010). A pre-exercise assessment will highlight 
factors that need to be considered when tailoring an exercise program. To date, validated 
and reliable assessments that combine all PL domains in one instrument are only available 
for children. However, healthcare providers may consider the assessment of the four PL
domains as separate (Edwards et al., 2017). Future studies may aim to develop an evidence-based assessment to measure and chart PL progress in older adults.

Contraindications of PA implementation are unusual. However, considering the complexity and relatively new development of AVG tools, precautions are necessary when older adults present with severe biopsychosocial impairments. Special attention must be provided for those presenting with deficits in social support, decreased motivation, self-efficacy, range of motion, elevated levels of injury-related fear, muscular weakness, persistent fatigue, joint swelling, or pain.

Given the general diversity and vulnerability characteristics of older adults, an AVG-based exercise program should start with the creation of a comprehensive and realistic plan. As seen in traditional physical exercises program, the use of AVG should be prescribed by a healthcare provider who understands the physical and cognitive level of the recipients, and are trained to use of AVG for older adults. Often recipients and providers are not actively involved during AVG design. Although participation in the design process could be a challenge if the recipient suffers from severe physical or cognitive limitations, inputs from recipients and providers would guide the designers to produce AVG systems that fit the populations’ contexts in which they are intended to support. Ultimately, AVG-based exercises should be designed and prescribed within the spheres of promotion, prevention, treatment/intervention, habilitation and rehabilitation (Figure 3.3).
Sedentary older adults who intend to start practicing regular physical exercise, AVG offer a great opportunity due to its adjustable nature. For those with physical and cognitive impairments, it is important to highlight that regular and oriented exercises are safe and can improve functional capacity and independence (Elsawy & Higgins, 2010). For those with injuries or illness, breaks may be necessary until the individual can recover and get back to the previous PL level (Elsawy & Higgins, 2010). Recipients presenting unhealthy conditions must take advantage not only from physical or cognitive benefits of using AVG, but also rely on the motivational and social aspects to increase confidence when performing PA and persist on its regular engagement.

Age-related characteristics can limit the possibilities of participating in regular PA and may lead to unique AVG design requirements. Designing AVG that address the impact
of age on structural elements of games may help older adults achieve the benefits of PA. As a novel therapy tool, implementing some adaptations are needed when using AVG with the elderly, especially those who present mobility or cognitive disorders. Commercial AVG devices are not designed for the elderly, and many of them may demand fast movements from the player, potentially increasing the risk of falling during the activities. Considerations when adapting AVG for older adults should include appropriate audio-visual feedback for effective learning, adaptive rules, game difficulty and speed levels, and avoidance of multiple distractors on the VEs.

Despite well-established guidelines, the criteria for types of exercise, frequency, duration, and intensity progression of exercise sessions needs to be addressed according to the recipients’ needs (Vearrier, Langan, Shumway-Cook, & Woollacott, 2005). In general, starting with light-intensity AVG that provide aerobic, resistance, balance, and flexibility training, two to three times a week and slowly increasing in progression are highly recommended. According to the meta-analysis by Zeng et al. (2017), AVG-based intervention lengths on clinical populations ranged from 4 to 26 weeks with the median intervention length being 6.5 weeks. However, measuring outcomes at 6 months and 1 year following the intervention would better determine long-term effects of the intervention as well as the most effective length for the program (Chao, Scherer, Montgomery, Wu, & Lucke, 2015).

Offering age appropriate experiences that include social interaction and enjoyment of the activities would provide older adults with a positive environment, and possibly influencing others to participate in PA. Choosing AVG that include a wide range of activities to target multiple abilities may be an important contribution to increasing PL
levels in older adults. Ideally, an AVG-based exercise program should provide a range of activities that will appeal to diverse senior groups, promoting functional activities of daily living in order to encourage independence and lifelong participation. For those in rehabilitation, providing a patient-specific feedback which facilitates healthcare providers to track progresses over time is recommended.

In the context of behaviour change, several theoretically driven studies have identified PA behaviour determinants, such as intention, motivation, and stage of change (Broekhuizen, Kroeze, van Poppel, Oenema, & Brug, 2012; Durand, Nigg, & Geriatrics, 2016). However, few of those studies are dedicated to understanding the determinants among older adults. Incorporating elements of comprehensive theoretical models, such as self-determination theory, health action process approach, organizational readiness for change, among others may create opportunities for future multidisciplinary development of technologies to address sedentary behaviour and life-long PA engagement.

For long-term benefits and adherence, combining AVG that continuously stimulate the four domains of PL with different types of exercise programs are central to sustaining overall health and wellness. From a macro-level perspective, government initiatives including technology-based exercise programs to prevent sedentary lifestyles may be effective in improving PL for older adults.

3.11 Conclusion

The application of PL concepts to older adults is still in its infancy. However, current research provides a useful guide to the applications of AVG to older adults’ PL. Implementing AVG into traditional PA programs by healthcare providers and AVG designers may rely on PL concepts to contextualize older adults’ profile, including their
motivation and confidence, physical competence, knowledge and understanding, and daily PA behaviour, to their environmental conditions and specific needs.

The older adult population is very heterogeneous in terms of culture/ethnicity, health, education, and experience with technology. Thus, researchers and practitioners should consider the wide range of abilities, needs, and desires of older users when using AVG for PL enhancement. Given the diverse area of implementation, including leisure, entertainment, PA promotion, functional maintenance, and rehabilitation, AVG program needs to address the proper activities, and easily accessible locations, possibly offering a group-based exercise program, in which older adults feel comfortable participating.

3.12 Acknowledgements

The authors would like to thank the Sport Technology Research Laboratory – University of Calgary, which provided the infrastructure for the development of this paper; and CAPES, a funding agency of the Brazilian government that has sponsored the PhD program of the first author of this paper (Grant: 99999.000400/2014-09).
Chapter Four: The Effects of Exergame Training on Community-Dwelling Seniors’ Physical Literacy: A Randomized Controlled Trial

4.1 Abstract

Objective: This study investigates the effects of an exergame training program on the four domains of physical literacy in community-dwelling older adults. Materials and Methods: A single-blind, randomized controlled trial compared three physical exercise training conditions: Exergaming (n=15), Conventional (n=14), and No Training (n=11). Forty healthy older adults were randomized and allocated to one of the three groups. Interventions were conducted three times a week for six weeks, with the primary objective of improving functional mobility, daily step count, motivation, confidence, and knowledge about physical activity. Results: Functional mobility and extrinsic motivation factors improved after six weeks of exergame training and remained after nine weeks. Conclusion: Findings demonstrated that a six-week exergame training program for healthy community-dwelling older adults helps improve and maintains physical and affective domains of physical literacy.

Keywords: Nintendo Wii-U, Elderly, Older Adults, Virtual Reality, Physical Literacy

4.2 Introduction

The senior population is the fastest growing age group worldwide. According to the WHO (2018), by 2050, the world’s population of older adults is expected to nearly double from 12% to 22%, summing up to approximately 2 billion people. As people age, many aspects of their lives tend to change leading to a wide variety of vulnerabilities. Older adults are more vulnerable to biopsychosocial changes, such as isolation, dependence, and
reduced physical and cognitive functions, compared to younger age groups (Briggs et al., 2016; Rossini, Rossi, Babiloni, & Polich, 2007). These age-related changes may be related to the adoption of unhealthy lifestyle choices (e.g., decreased physical activity (PA), poor nutrition, etc.) (Demnitz et al., 2018; Sun, Norman, & While, 2013). According to Michel, Dreux, and Vacheron (2016), the most important factors of successful healthy aging are the daily habits, such as well-balanced nutrition, social interaction, and PA practices. In particular, the regular engagement in PA programs by older adults is effective in promoting social interaction, preventing age-related risks of chronic diseases, and reducing general physical and cognitive impairments (Buchner, Beresford, Larson, LaCroix, & Wagner, 1992; Ji et al., 2018; Lelard & Ahmaidi, 2015).

Despite the known positive effects of PA engagement, only 25% of older adults meet the recommended levels of PA proposed by the WHO (2010). The major barriers reported as possible reasons to avoid PA include the lack of time and motivation, physical disorders, presence of chronic diseases, and fear of injuries (De Groot & Fagerström, 2011; Schutzer & Graves, 2004). Consequently, this avoidance may further decrease physical and cognitive functions and increase the risk of chronic diseases and injuries.

The higher demands for an active lifestyle are associated with the availability of and accessibility to activities afforded by the environment in which older adults live (Chaudhury, Campo, Michael, & Mahmood, 2016). The perception of everyday surroundings as unfavorable for PA practice increases disengagement, resulting in over-cautiousness and lack of confidence to perform PA (McGowan, Devereux-Fitzgerald, Powell, & French, 2018). Insecurity to perform PA can be responsible for long-term
sedentary lifestyles, physical disabilities, and loss of fine and gross motor skills (Jacobs, 2017).

Daily PA practices, social interactions, physical competence, motivation, and confidence are related to the development of physical literacy (PL) throughout one’s lifespan. PL is defined by Whitehead (2014) as the development of the motivation, confidence, physical competence, knowledge, and understanding to value and engage in a wide variety of physical activities and environments that benefit the person as a whole. Based on this definition, the International Physical Literacy Association (IPLA, 2015) has published a consensus on the four PL domains: physical (mobility skills), affective (motivation and confidence), cognitive (knowledge and understanding about PA), and behavioural (daily exertion). Over time, PL levels may fluctuate depending on factors such as age, health status, daily habits, PA engagement, participation in sports, workplace demands, and preferred interests (Loitz, 2013). Although PL may be developed at any age, it typically takes more time and practice for older adults to learn or recover their physical and cognitive skills, especially when compared to their earlier years (Jones et al., 2018; Loitz, 2013).

The exposure to multi-component physical exercise programs including aerobics, flexibility, muscle strengthening, and balance training combined to a variety of environments is recommended for the early development of PL (Mandigo, Francis, Lodewyk, & Lopez, 2009). Early exposure to PA may be effective to establishing early PL development, lifelong PA participation, and preventing a number of functional declines in later life (Gillespie et al., 2003; Paw, Chin, van Uffelen, Riphagen, & van Mechelen, 2008; Robitaille et al., 2005; Theou et al., 2011). Furthermore, long-term PA engagement is also
associated with greater odds of physical-psychosocial successful aging (Dogra & Stathokostas, 2012). However, the practice of conventional exercise programs is often considered monotonous and boring among older adults, leading to loss of interest and discontinuation of regular practices (Chao, Scherer, & Montgomery, 2015). Therefore, effective approaches that emphasize task-oriented training and motivate self-regulated practice are needed in order to maintain PL levels, long-term quality of life, and functional capabilities (Gillespie et al., 2003; Robitaille et al., 2005).

Innovative tools for practicing physical exercises and monitoring PA parameters have gained notable research focus as they may represent an alternative to conventional approach to engage in healthier lifestyles (Hasselmann, Oesch, Fernandez-Luque, & Bachmann, 2015). Recent technological advances, such as fitness trackers and virtual-reality (VR)-based exercises have been designed to encourage people to engage in PA (Brooks, Brahnam, Kapralos, & Jain, 2017). Fitness trackers encompass a broad range of research- and consumer-grade wearable devices worn anywhere on the body. Their potential is further amplified due to its portability and ability to monitor health and wellness for later life independence (Kim, Gollamudi, & Steinhubl, 2017; Peetoom, Lexis, Joore, Dirksen, & De Witte, 2015). In its turn, VR has been employed in exercise programs, usually in the form of active video games, also called exergames, due to VR’s unprecedented ability to stimulate auditory and visual sensations (Cherniack, 2011). Immersed in a virtual environment, exergame users can practice PA simulating what they would do in the real world.

As an interactive tool exergaming is perceived as an enjoyable experience, which makes the activity more accessible and motivates older adults to engage and adhere to
exercise programs (Campelo & Katz, 2020; Van Diest, Lamoth, Stegenga, Verkerke, & Postema, 2013; Yardley, Donovan-Hall, Francis, & Todd, 2006). Evidence supports that the use of exergames as rehabilitation tools can improve physical and cognitive functions, such as balance, mobility, muscle strengthening and flexibility, executive function, and processing speed (Bieryla & Dold, 2013; Jorgensen, Laessoe, Hendriksen, Nielsen, & Aagaard, 2012; Larsen, Schou, Lund, & Langberg, 2013; Maillot et al., 2012; Skjæret et al., 2016).

Considering the predominantly sedentary behavior among older adults, and the adherence and compliance problems with conventional exercise programs, there is a need to use more innovative approaches, such as the PL concepts and new technologies to improve interest and participation. The purpose of this study is to evaluate the use of fitness trackers and exergame technologies in a prescribed exercise program for older adults, to measure their mobility skills, daily exertion, motivation, confidence, and knowledge about PA when compared to a conventional exercise program and a no training group. It is hypothesized that participants randomly assigned to the exergame training group will experience and retain benefits in each of the dependent variables, including functional mobility task in seconds, number of daily steps, and survey scores of motivation, confidence, and knowledge about PA.

4.3 Method

4.3.1 Study Design

This study is a randomized-controlled trial (RCT) that was conducted at an independent-living centre located in Calgary, Canada, from September 2018 to December
2018. The Conjoint Health Research Ethics Board (CHREB), University of Calgary approved the study under the reference protocol number REB16-1633.

### 4.3.2 Sample and Selection Criteria

Participants were recruited from a sample of residents from 15 community centers and 3 retirement centers located in Calgary, Alberta, Canada (APPENDIX C). All 58 volunteers who expressed an interest in starting an exercise program were pre-screened prior to group randomization by a physical therapist. The pre-screening (APPENDIX D) was based on guidelines from the American College of Sports Medicine (ACSM, 2013) and also included a cognitive function assessment via Mini-Cog Test (Borson, Scanlan, Chen, & Ganguli, 2003) (APPENDIX E and F). Volunteers were excluded of the study if they: (1) were diagnosed with balance or neurological disorders that seriously affect physical function (e.g., stroke, traumatic brain injury, spinal cord injury, nerve injury, Multiple Sclerosis or Parkinsonism); (2) took part in a PA program within last three months; (3) presented active acute/chronic disease process (PARQ-Plus form) (APPENDIX G); (4) failed to clear the Mini-Cog Test (score < 3). After clearing the pre-screening tests and exclusion criteria, eligible participants were (1) 65 years-old or older; (2) able to ambulate independently without an assistive device; (3) presented adequate vision and hearing to interact with a videogame; (4) able to read and speak English. A total of 40 participants who fulfilled the study criteria were included in the study. Subjects were subsequently randomly allocated to one of the three groups: Exergame Training (ET; n=15), Conventional Training (CT; n=14), and No Training (NT; n=11). To maintain allocation concealment, randomized sequences were computer-generated by an individual
that was not directly involved in the study. All participants signed a consent form agreeing to partake each phase of the study (Figure 4.1) (APPENDIX H and I).

4.3.3 Intervention Programs

The study addressed the application of Whitehead’s PL concepts to investigate the effect of exercise trainings on older adults’ daily step count, physical function, self-confidence, motivation, and knowledge about PA. Both the exergame and conventional physical exercise training programs were designed to match the exercise components (warm-up, aerobics, strength, flexibility, balance, and cool-down) and were led by two instructors, including a physical therapist and an assistant assigned for each group.
Exercise training sessions occurred concurrently in two separate rooms within the independent-living centre, two of which occurred in the morning and one in the afternoon. Participants from each exercise training group were offered to choose one of the three different session times, and further divided into smaller groups of 4 to 5 older adults according to the session time they chose. Sessions were conducted three times a week for six weeks. The exercise time per session ranged between 40-50 minutes.

Staff members, including both physical therapists, assistants, and a study coordinator were enrolled in a standardized training session prior to delivering the exercise programs. The staff training was delivered by the principal investigator. Staff members received a standardized booklet outlining the key objectives of the programs, the content details for each week, and were encouraged to: (1) create a supportive social environment; (2) maximize participants’ opportunities to be physically active during the sessions; (3) satisfy participants’ needs for autonomy by including elements of choice, when possible; (4) deliver experiences that were fair by allowing all participants to experience success regardless of their capabilities; and (5) ensure the safety of participants by continuous supervision during the exercise sessions.

Participants were provided with their program schedule and asked not to enroll in any other structured physical exercise program but maintain their usual daily activities. All participants wore a Fitbit Flex 2™ (Fitbit Inc., San Francisco, United States) for the duration of the study (nine weeks) in order to monitor their daily activity. Participants from CT and ET groups downloaded the Fitbit data once a week before training. The participants in the NT group were asked to commute to the community facility once a week to meet with the research coordinator to download the Fitbit data, but did not have
contact with the other groups. Participants did not have access to the data from the Fitbit until the end of the study.

4.3.3.1 No Training

Participants allocated in the No Training (NT) group were asked not to engage in any organized exercise training. They were advised to maintain their usual daily routine. Their daily activities were weekly monitored via Fitbit.

4.3.3.2 Exergame Training

The videogame console used for the Exergame Training (ET) was the Nintendo Wii-U and the subgames from Wii Fit-U (Bieryla & Dold, 2013) (APPENDIX J). The sessions began with a warm-up exergame (e.g., walk in place), then participants performed a strength exergame (e.g., lunge), two balance exergames (e.g., penguin slide and table tilt), and two yoga exergames (e.g., chair position, deep breathing). The games were considered simple and had features that could be easily understood by the participants (Bieryla & Dold, 2013). The participants used the Wii Balance Board and Wii Remote to control the game target element shown on the screen, while moving on both the sagittal and frontal planes. The initial screen of each game allowed the participants to understand the game, what type of body movements they required, and to select games’ difficulty level. The instructors demonstrated how each game should be played and assisted participants when selecting the game difficulty level to achieve their best performance.

The games’ difficulty levels were gradually increased by the instructors every two weeks in an effort to achieve positive effect of the exercise program. However, the actual progression criteria after the first two weeks depended on each individual’s perception on
their physical abilities (e.g., coordination, agility) and performance on the games (e.g.,
games’ score, time remaining to complete the tasks) (APPENDIX K).

4.3.3.3 Conventional Training

The conventional physical training (CT) was adapted from guidelines provided by
Kisner et al. (2017) but addressed the same physical ability components as the ET group
(APPENDIX L). The CT program consisted of exercises done seated on a chair, standing
behind the chair, and laid down on an exercise mat. Each of the CT sessions started with a
warm-up period of 10 min covering the large muscle groups, such as the quadriceps,
hamstrings, gluteals, biceps brachialis, deltoid, and pectoralis. The following 25 minutes
were composed by strengthening and flexibility exercises. The training session was
finished with a 10-min cooling-down period, including balance exercises. The intensity of
the exercises was established by each participant. Elastic bands and ankle weights were
used to progress resistance and difficulty. The resistance was chosen so that the
participants were able to complete their full three sets of each exercise. Difficulty of each
exercise component was increased every two weeks and was individually tailored.

4.3.4 Outcome Measures

Outcome measures included a group of standardized measures of height, weight,
functional mobility, daily step count, motivation, confidence, and knowledge about PA to
evaluating the change following treatment with exergame-based, conventional exercise
program or no training. These measures were selected to characterize the sample
demographics and evaluate each of PL domain: physical (mobility skills), affective
(motivation and confidence), cognitive (knowledge and understanding about PA), and
behavioural (daily exertion). Outcome measures were administered at pre-intervention

69
(week 0), post-intervention (week six) and at the time of final follow-up (week 9). Due to the time of the year when the intervention was conducted (Fall) follow-up testing was performed three weeks post intervention to avoid a potential of participants dropping out because of the holiday season.

An independent, blinded study physical therapist served as the primary evaluator for height, weight, and functional mobility. In order to minimize experimenter bias, the study coordinator administered the surveys, scheduled the order of the assessments, and was responsible for downloading the Fitbit data of all participants. Neither the staff members delivering the programs, nor the participants assigned to the exercise programs were blinded to the intervention. Participants in the No Training group were aware of both exercise programs.

### 4.3.4.1 Demographic Characteristics

Demographic and anthropometric data were obtained at baseline (week 0) to characterize the sample, and included age (years), sex (male or female), height (cm), weight (kg), and body mass index (BMI) (kg/m²).

### 4.3.4.2 Physical Competence

**Timed Up and Go Test (TUG)**

TUG (APPENDIX M) is a measure of functional mobility created by Shumway-Cook, Brauer, and Woollacott (2000). The participants wore their regular footwear and started the test sitting on a chair. On the tester command, they stood up, walked 3 meters, turned around, walked back, and sat down. The time taken to complete this task was recorded in seconds with a stopwatch (Casio, HS70W, Japan) and copied to a scoresheet. Prior literature evaluating the TUG in older adults between the ages of 65 and 97 (mean
age = 78±3.4) has demonstrated reliability, internal consistency, and validity (Medley & Thompson, 2005). Concurrent validity of the TUG to levels of functional mobility has also been demonstrated in older adults under 3 conditions: performance of the TUG alone; performance of the TUG with the addition of a cognitive task; and performance of the TUG with the addition of an upper-extremity motor task (Shumway-Cook et al., 2000).

4.3.4.3 Confidence

Exercise Confidence Survey (ECS)

The ECS (APPENDIX N) measured participants’ confidence to exercise in a variety of daily life conditions (Sallis, Pinski, Grossman, Patterson, & Nader, 1988). The 5-point Likert scale consisted of 12 items in which the participants were asked to rate their confidence from 1 to 5, in which 1 represented ‘I know I cannot’, and 5 ‘I know I can’. Higher scores indicated higher confidence or self-efficacy. This test has been found to be a reliable outcome measure with an alpha reliability coefficient of .92, and able to significantly predicts self-reported activity (Resnick & Jenkins, 2000).

4.3.4.4 Knowledge and understanding

Knowledge and Understanding Questionnaire (K&UQ)

The knowledge and understanding questionnaire (APPENDIX O) included seven open-ended questions about knowledge on the appropriate intensity, duration, and frequency of PA for achieving health benefits. The questions were originated from a validated questionnaire in assessment of PA knowledge among US citizens (Morrow, Krzewinski-Malone, Jackson, Bungum, & Fitzgerald, 2004). Participants answered with numbers in the first two questions, and "true/false" or "yes/no" in the following five questions. The first two questions were transformed to a score system, reaching from zero
to two, where zero was given for answers below the expected answer, one was given for the expected number, and two was given for answers above the expected. The sum of correct responses to these questions formed a knowledge score up to nine. For each participant. Previous study demonstrated high reliability ($\alpha = 0.81$) (Hui & Morrow, 2001).

4.3.4.5 Motivation

*Motives for Physical Activity Measure-Revised (MPAM-R)*

The MPAM-R (APPENDIX P) is a 30-item measure of motivation for PA participation. Participants were asked to answer the questionnaire which contained five motive subscales: competence–challenge motives (e.g., “I like physical challenges”), appearance motives (e.g., “I want to improve my appearance”), social motives (e.g., “I want to meet new people”), fitness–health motives (e.g., “I want to maintain my physical strength”) and enjoyment–interest motives (e.g., “I enjoy this activity”). Responses to each item were recorded on a 7-point scale ranging from 1 (not at all true for me) to 7 (very true for me).

This instrument has demonstrated satisfactory reliability for each subscale with Cronbach's $\alpha$ ranging from 0.78 to 0.92 (Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997). Adequate construct validity was confirmed by moderate correlation with psychological constructs (e.g., enjoyment–interest subscale was positively associated with competence (0.45), autonomy (0.48), and relatedness (0.32), postulated in self-determination theory (Wilson, Rodgers, & Fraser, 2002).
4.3.4.6 Daily Exertion Behaviour

Total Physical Activity Tracking (Wrist Wearable Device)

Each participant was provided with a wristband activity tracker, the Fitbit Flex 2™ (Fitbit Inc., San Francisco, United States). The device was worn on participants’ non-dominant wrist. Participants were instructed to wear the Fitbit for 24 hours a day during the full study period (nine weeks), starting one week prior to the beginning of the exercise programs. Participants were given written and verbal instructions to recharge the device overnight twice a week (APPENDIX Q).

The device measured daily exertion behaviour based on arm movement. The data recordings were transferred through Bluetooth connection directly to the Fitbit. The Fitbit Flex 2™ was chosen based on a combination of factors including simplicity, waterproof, and battery life in order to increase total wear time and compliance (Weisberg et al., 2020). Fitbit Flex series have shown to have moderate to strong concurrent validity in assessing sedentary behaviour (r = 0.90) and moderate-to-vigorous PA (r = 0.65–0.76) compared to ActiGraph GT3X+ (Redenius, Kim, & Byun, 2019).

4.3.5 Data Analysis

The sample size calculation was based on a distribution assuming three independent groups. The GPower software (V. 3.1.9, University of Dusseldorf, Germany) was used to calculate the power analysis of 0.78, considering the physical functioning, measured by the timed up and go test, as the primary outcome. With an effect size of \( f^2 = 0.8 \) and an error type I of 5%, a total sample size of 38 participants was estimated.

Means and standard deviations were used to inform demographic variables, age, height weight and body mass index (BMI). One-way analysis of variance (ANOVA) was
conducted to investigate differences in demographic information. The generalized estimating equation model (GEE, GENLIN) was employed to determine the longitudinal effects of the interventions on each of the dependent variables: functional mobility task in seconds, number of daily steps, and survey scores of motivation, confidence, and knowledge about PA. An alpha level of $\alpha = 0.05$ was chosen and any computed $p$-values less than $p < 0.05$ were considered statistically significant. The analysis determined the group, phase, and group by phase interaction effects. In the case of a significant main effect, a post-hoc pairwise comparison (with Bonferroni correction) was used to determine which conditions differed from another. Data coding and statistical analysis was completed using IBM® Statistical Package for the Social Sciences (SPSS) version 23.0.

### 4.4 Results

#### 4.4.1 Demographics

A total of 40 eligible older adults (15 males and 25 females) from 65 to 95 years of age participated in this study. No adverse events were reported during the intervention. In the 3-week follow-up after the intervention, there were 4 dropouts (1 in the ET, 1 in the NT, and 2 in the CT) due to lack of time commitment and unwillingness to travel to the exercise facility after post-test; the follow-up completion rate was 90% (36/40). The mean and standard deviation of participants’ attendance was $14.5 \pm 2.92$ sessions in the ET group and $15 \pm 2.40$ in the CT group, out of 18 session in total.

Demographic characteristics of each group are listed in Table 4.1. Considering the baseline characteristics, the one-way ANOVA showed a significant difference in BMI between the three study groups ($P = 0.03$), in which ET group presented a higher BMI compared to the other two experiment group. No significant differences were found in the
other demographic variables. Therefore, only BMI was treated as covariate for data analysis (Cook, 1979).

Table 4.1 Demographic variables’ means, standard deviation, and analyses of variation between groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>ET (n=15)</th>
<th>CT (n=14)</th>
<th>NT (n=11)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>72 (±6.4)</td>
<td>70.4 (±5)</td>
<td>76 (±9.8)</td>
<td>0.98</td>
</tr>
<tr>
<td>Female</td>
<td>73.4 (±9.4)</td>
<td>73.4 (±4.9)</td>
<td>71.7 (±5.7)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>72 (±6.4)</td>
<td>73.4 (±9.4)</td>
<td>70.4 (±5)</td>
<td>76 (±9.8)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.8 (±4.1)</td>
<td>173.6 (±3.6)</td>
<td>173 (±11.3)</td>
<td>0.72</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>97 (±19.3)</td>
<td>92.4 (±17.1)</td>
<td>80.1 (±24.7)</td>
<td>0.06</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>32.8 (±6.4)</td>
<td>30.5 (±5)</td>
<td>26.39 (±4.8)</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

Abbreviations: ET - Exergame Training; CT - Conventional Training; NT - No Training; BMI – Body Mass Index; n – number of participants.

The within-groups comparisons of total scores, and the GEE tests of model effects for each variable adjusted for BMI are shown in Table 4.2 and Table 4.3, respectively.

Despite the randomized allocation of the participants into each group, there was a conspicuous difference at baseline, in which ET group presented a trend toward worse performance than the other two groups.

Table 4.2 Variables’ means, standard deviations of each group, and comparison within groups by phases of the study.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Pre-test (Mean±SD)</th>
<th>Post-test (Mean±SD)</th>
<th>Follow-Up (Mean±SD)</th>
<th>Wald χ²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG (seconds)</td>
<td>CT 8.44 (±0.36)</td>
<td>8.44 (±0.26)</td>
<td>9.06 (±0.5)</td>
<td>3.17</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>ET 10.04 (±0.49)</td>
<td>8.98 (±0.32)</td>
<td>8.98 (±0.42)</td>
<td>27.35</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>NT 8.7 (±0.38)</td>
<td>9.4 (±0.47)</td>
<td>9.28 (±0.46)</td>
<td>16.81</td>
<td>0.00*</td>
</tr>
<tr>
<td>Exercise Confidence Survey (Total score)</td>
<td>CT 52.42 (±2.02)</td>
<td>49.01 (±2.54)</td>
<td>52.33 (±2.13)</td>
<td>3.72</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>ET 50.19 (±1.78)</td>
<td>50.13 (±2.5)</td>
<td>46.26 (±3.37)</td>
<td>2.35</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>NT 59.09 (±3.2)</td>
<td>57.09 (±3.97)</td>
<td>59.92 (±3.51)</td>
<td>1.27</td>
<td>0.53</td>
</tr>
<tr>
<td>Knowledge and Understanding Questionnaire (Total score)</td>
<td>CT 7.11 (±0.42)</td>
<td>7.86 (±0.40)</td>
<td>7.61 (±0.29)</td>
<td>5.40</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>ET 7.22 (±0.37)</td>
<td>7.08 (±0.28)</td>
<td>7.33 (±0.31)</td>
<td>1.00</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>NT 7.16 (±0.41)</td>
<td>6.7 (±0.50)</td>
<td>7.42 (±0.46)</td>
<td>3.68</td>
<td>0.16</td>
</tr>
<tr>
<td>Motives for Physical Activity Questionnaire-Revised (Total score)</td>
<td>CT 165.76 (±4.88)</td>
<td>156.41 (±7.46)</td>
<td>160.80 (±6.83)</td>
<td>1.81</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>ET 139.97 (±7.42)</td>
<td>140.63 (±8.40)</td>
<td>139.00 (±8.45)</td>
<td>0.15</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>NT 154.75 (±7.07)</td>
<td>153.30 (±8.73)</td>
<td>159.33 (±9.99)</td>
<td>1.23</td>
<td>0.54</td>
</tr>
<tr>
<td>Daily Step Count (Number of steps)</td>
<td>CT 7177.17 (±1698.32)</td>
<td>7600.49 (±797.28)</td>
<td>8116.38 (±899.92)</td>
<td>2.02</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>ET 5683.27 (±1238.34)</td>
<td>6631.4 (±789.62)</td>
<td>6504.54 (±743.58)</td>
<td>3.85</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>NT 7078.36 (±272.62)</td>
<td>6552.1 (±532.12)</td>
<td>6884.43 (±556)</td>
<td>2.98</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Abbreviations: ET - Exergame Training; CT - Conventional Training; NT - No Training; SD – Standard Deviation; TUG – Timed Up and Go Test; * - P < 0.05
### Table 4.3 GEE Test of Model Effects of each dependent variable

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Main Effect</th>
<th>Wald $\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG (seconds)</td>
<td>Group</td>
<td>1.95</td>
<td>2</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>1.33</td>
<td>2</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>46.04</td>
<td>4</td>
<td>0.00*</td>
</tr>
<tr>
<td>Exercise Confidence Survey (Total score)</td>
<td>Group</td>
<td>7.81</td>
<td>2</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>2.94</td>
<td>2</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>5.33</td>
<td>4</td>
<td>0.26</td>
</tr>
<tr>
<td>Knowledge and Understanding Questionnaire (Total score)</td>
<td>Group</td>
<td>1.60</td>
<td>2</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>0.92</td>
<td>2</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>9.43</td>
<td>4</td>
<td>0.06</td>
</tr>
<tr>
<td>Motives for Physical Activity Questionnaire-Revised (Total score)</td>
<td>Group</td>
<td>5.17</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>1.36</td>
<td>2</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>2.54</td>
<td>4</td>
<td>0.64</td>
</tr>
<tr>
<td>Daily Step Count (Number of steps)</td>
<td>Group</td>
<td>2.13</td>
<td>2</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>2.44</td>
<td>2</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>7.57</td>
<td>4</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Abbreviations: ET - Exergame Training; CT - Conventional Training; NT - No Training; df – degrees of freedom; TUG – Timed Up and Go Test; * - P < 0.05

#### 4.4.2 Functional Mobility

The GEE analyses result for TUG scores did not significantly differ among groups (Wald $\chi^2 = 1.95$, p = 0.37) at any phase of the study (Wald $\chi^2=1.33$, p=0.51). Moreover, significant group by phase interaction effects (Wald $\chi^2=46.04$, p = 0.00) was observed for TUG scores. The within-group comparison showed significant differences in the ET and NT groups from pre- to post-test (p=0.00, p=0.00, respectively) and from pre- to follow-up-test (p=0.00, p=0.00, respectively) (Fig. 4.2).
4.4.3 Confidence

No significant differences in ECS scores were found within-groups at any phase of the study (Table 4.2). The GEE revealed a significant main effect of group in ECS scores (Wald $\chi^2=7.81$, $p=0.02$) (Table 4.2). Further post-hoc test indicated that ET and CT groups were statistically different ($p=0.02$).

4.4.4 Knowledge and Understanding

No significant differences in K&UQ scores between and within groups were revealed by GEE analysis at any phase of the study (Table 4.2). However, there were trends indicating that participants in the CT group performed better in the K&UQ from pre- to post-test ($p=0.07$).
4.4.5 Motivation

No differences in MPAM-R total scores were found within-groups at any phase of the study (Table 4.2). The within-groups comparisons of MPAM-R subscores, and the GEE tests of model effects for each MPAM-R subscale, interest, competence, appearance, fitness-health, and social, adjusted for BMI are provided in Table 4.4 and Table 4.5, respectively.

Table 4.4 MPAM-R Subscales’ means, standard deviations of each subscore, and comparison within groups.

<table>
<thead>
<tr>
<th>MPAM-R Subscales</th>
<th>Pre-Test (Mean±SD)</th>
<th>Post-Test (Mean±SD)</th>
<th>Follow-Up (Mean±SD)</th>
<th>Wald $\chi^2$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interest (Subscore)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>5.86 (±0.20)</td>
<td>5.41 (±0.34)</td>
<td>5.55 (±0.31)</td>
<td>2.49</td>
<td>0.29</td>
</tr>
<tr>
<td>ET</td>
<td>4.93 (±0.30)</td>
<td>5.05 (±0.36)</td>
<td>4.97 (±0.31)</td>
<td>0.27</td>
<td>0.88</td>
</tr>
<tr>
<td>NT</td>
<td>5.63 (±0.35)</td>
<td>5.64 (±0.31)</td>
<td>5.76 (±0.41)</td>
<td>0.31</td>
<td>0.86</td>
</tr>
<tr>
<td><strong>Competence (Subscore)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>5.83 (±0.21)</td>
<td>5.61 (±0.27)</td>
<td>5.56 (±0.28)</td>
<td>0.84</td>
<td>0.66</td>
</tr>
<tr>
<td>ET</td>
<td>4.56 (±0.44)</td>
<td>4.74 (±0.40)</td>
<td>4.64 (±0.38)</td>
<td>0.53</td>
<td>0.77</td>
</tr>
<tr>
<td>NT</td>
<td>5.14 (±0.32)</td>
<td>5.02 (±0.36)</td>
<td>5.48 (±0.37)</td>
<td>1.99</td>
<td>0.37</td>
</tr>
<tr>
<td><strong>Appearance (Subscore)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>5.05 (±0.32)</td>
<td>4.65 (±0.35)</td>
<td>4.95 (±0.32)</td>
<td>2.098</td>
<td>0.35</td>
</tr>
<tr>
<td>ET</td>
<td>4.14 (±0.31)</td>
<td>4.02 (±0.31)</td>
<td>4.15 (±0.32)</td>
<td>0.30</td>
<td>0.86</td>
</tr>
<tr>
<td>NT</td>
<td>4.09 (±0.37)</td>
<td>4.03 (±0.44)</td>
<td>4.42 (±0.41)</td>
<td>2.11</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Fitness-health (Subscore)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>6.65 (±0.13)</td>
<td>6.47 (±0.20)</td>
<td>6.52 (±0.15)</td>
<td>1.46</td>
<td>0.48</td>
</tr>
<tr>
<td>ET</td>
<td>5.51 (±0.29)</td>
<td>5.60 (±0.32)</td>
<td>6.18 (±0.21)</td>
<td>10.38</td>
<td>0.01*</td>
</tr>
<tr>
<td>NT</td>
<td>6.40 (±0.25)</td>
<td>6.51 (±0.13)</td>
<td>6.27 (±0.25)</td>
<td>1.79</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>Social (Subscore)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>4.39 (±0.27)</td>
<td>4.13 (±0.35)</td>
<td>4.34 (±0.42)</td>
<td>1.53</td>
<td>0.46</td>
</tr>
<tr>
<td>ET</td>
<td>3.87 (±0.38)</td>
<td>4.18 (±0.32)</td>
<td>3.96 (±0.33)</td>
<td>2.30</td>
<td>0.32</td>
</tr>
<tr>
<td>NT</td>
<td>4.61 (±0.27)</td>
<td>4.51 (±0.47)</td>
<td>4.67 (±0.48)</td>
<td>0.47</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Abbreviations: ET - Exergame Training; CT - Conventional Training; NT - No Training; SD – Standard Deviation; TUG – Timed Up and Go Test; * - P < 0.05
Table 4.5 GEE Test of Model Effects of each MPAM-R Subscales.

<table>
<thead>
<tr>
<th>MPAM-R Subscales (Subscore)</th>
<th>Main Effect</th>
<th>Wald $\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest</td>
<td>Group</td>
<td>3.54</td>
<td>2</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>0.53</td>
<td>2</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>2.71</td>
<td>4</td>
<td>0.61</td>
</tr>
<tr>
<td>Competence</td>
<td>Group</td>
<td>6.21</td>
<td>2</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>0.63</td>
<td>2</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>3.22</td>
<td>4</td>
<td>0.52</td>
</tr>
<tr>
<td>Appearance</td>
<td>Group</td>
<td>4.61</td>
<td>2</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>3.38</td>
<td>2</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>1.41</td>
<td>4</td>
<td>0.84</td>
</tr>
<tr>
<td>Fitness-health</td>
<td>Group</td>
<td>8.22</td>
<td>2</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>9.86</td>
<td>2</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>8.05</td>
<td>4</td>
<td>0.09</td>
</tr>
<tr>
<td>Social</td>
<td>Group</td>
<td>1.67</td>
<td>2</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>Phase</td>
<td>0.13</td>
<td>2</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Group * Phase</td>
<td>3.56</td>
<td>4</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Abbreviations: ET - Exergame Training; CT - Conventional Training; NT - No Training; df – degrees of freedom; TUG – Timed Up and Go Test; * - P < 0.05

No differences in interest, competence, appearance, and social subscale scores were found between-groups at any phase of the study. Significant main effects of group (Wald $\chi^2=8.22$, p=0.02) and phase (Wald $\chi^2=9.86$, p=0.01) was revealed by GEE analysis for fitness-health subscale scores. Despite the trend, no significant group by phase interaction effect (Wald $\chi^2=8.05$, p = 0.10) was observed for fitness-health subscale scores. Further post-hoc test indicated that ET and CT groups, and pre-test and follow-up phases were statistically different (p=0.01, p=0.01, respectively). The within-group comparison showed significant differences in the ET group from pre- to post-test (p=0.01) and from pre- to follow-up-test (p=0.01) (Fig. 4.3).
No statistically differences in number of steps between and within groups were revealed by GEE analysis at any phase of the study (Table 4.3).

4.5 Discussion

This single-blinded RCT aimed to compare the effects of an exergame-based to a conventional exercise program and no training on each of the four domains of PL (physical, affective, cognitive, and behavioural) of healthy community-dwelling older adults. The results of the present study indicate that using exergames on a six-week exercise program improved the primary outcome measure of functional mobility measured via TUG test. Moreover, participants in the ET group were able to decrease their time to complete TUG test to reach normative value (Shumway-Cook et al., 2000), while participants in the NT group increased their TUG results. These findings agree with a
systematic review on exercise programs delivered through exergames in older adults, in which four studies indicated improvements on TUG test in favor of the exergame groups, however other four studies did not observe this (Skjær et al., 2016). The conflicting findings may be due to different exercise components and the inclusion of clinical population targeted in the studies.

The improved performance in the TUG test may be related to an increased self-confidence and reduced fear of falling (Singh, San, Ping, Rahman, & Selvam, 2018). Furthermore, self-confidence may be associated with cognitive functions due to the feeling of being able to understand how the technological devices work and improve their performance in novel activities, such as the Nintendo Wii games (Hwang et al., 2009; Orsega-Smith, Kalksma, Harris, & Drazich, 2020). Despite improvements on TUG test in favor of ET group, there were no significant differences in confidence and knowledge about PA. These findings contrast to the findings from Williams, Soiza, Jenkinson, and Stewart (2010), who demonstrated significant improvements in self-confidence on healthy community-dwelling older adults after a 12-week exergame intervention. It is possible that both the length of the intervention and the different study design played a role in the differences seen in the present study. In addition, knowledge and understanding about PA were not directly addressed by either of the exercise programs in the present study. An exergame program combined with an education intervention might improve the knowledge and understanding about PA.

Fitness activities that are interactive, challenging, competitive, and more rewarding than conventional exercise programs are more motivating for older adults to engage (Loos, 2017). Moreover, contexts fostering autonomy and perceived competence may enhance
enjoyment and sustained motivation (Chatzisarantis, Hagger, Biddle, & Karageorghis, 2002; Hagger & Armitage, 2004; Hagger, Chatzisarantis, Culverhouse, & Biddle, 2003; Hagger, Chatzisarantis, & Harris, 2006). The feedback on participants’ performance provided by exergames is more appealing and rewarding than conventional exercises (Fitzgerald, Trakarnratanakul, Smyth, & Caulfield, 2010). The fun and entertaining capacity that exergames’ interactive environment can provide, and the immediate performance feedback may keep participants motivated to continue PA engagement (Smith & Schoene, 2012; Taylor, Kerse, Frakking, & Maddison, 2018). According to Derakhshanrad, Piven, and Ghoochani (2020), PA engagement by older adults is often due to extrinsic goals, such as wellness and socialization. Although data analyses have not demonstrated significant differences on the total motivation score, participants from ET group significantly improved their MPAM-R fitness-health sub-scores. Despite no significant differences in the MPAM-R social and enjoyment–interest motives subscales, participants from ET group also reported perceived enjoyment while exercising with their peers (Campelo & Katz, 2020). An increased extrinsic motivation to be fit and healthy, and the enjoyment of peer socialization while engaging in PA may contribute to higher adherence rate to exercise programs.

Adherence is considered as one of the challenges to implementing exercise programs for older adults, since the beneficial effects may decline if regular attendance is not maintained. While the exercise training programs in the present study provided intensive schedules, requiring a three-day weekly attendance for six weeks, the achieved attendance level in the ET group (80.5%) is in line with previous studies (Konstantinidis et al., 2014; Rosenberg et al., 2010). Participants in our study attended nearly all the offered
sessions and there were no adverse events indicating that the Nintendo Wii Fit subgames and their difficulty progression were engaging and feasible on their routines. However, specifically average daily step count, was not significantly different after the six-week intervention. Systematic reviews in the field point out the need for additional research in the long-term behavioural change using exergames (Chao, Scherer, & Montgomery, 2015; Larsen et al., 2013).

4.6 Limitations

There are some limitations to this study that should be taken into consideration. First, despite randomization and allocation concealment processes, the NT group was smaller than the intervention groups and ET group’s BMI was significantly higher than the other two groups. Despite no other group differences at baseline, the higher BMI may explain the lower performance of ET group, compared to the other two groups on most of the outcome measures. Janney and Jakicic (2010) suggested that a high BMI may be a factor preventing people from exercising and may contribute to the onset of injury and illness. In addition, the sample included participants with an age-range of 30 years (from 65 to 95 years of age), however, none of the participants presented with injuries and thus were considered eligible to the study according to the inclusion and exclusion criteria. Participants were also considered physically active, presenting high motivation and confidence levels prior to engaging in the exercise programs. Therefore, our findings may not be generalized to a heterogeneous population of older adults.

The length of the intervention and the short period from post- to follow-up tests may also be considered limitations of the study. According to a recent meta-analysis on the effects of active computer gaming in older adults, the average intervention length of 35
RCTs was 12 weeks (Howes, Charles, Marley, Pedlow, & McDonough, 2017). Moreover, the dropout rate of 10% after the post-test may be explained by the season that the study occurred and the feeling of mastery of the activities and assessments. When this feeling is achieved, through finishing the exercise programs or repeating the same tests in a short period of time, participants may discontinue the study. Nonetheless, the follow-up tests were anticipated to early December, when average temperature was colder and snow precipitation was higher compared to the period in the beginning of the study. Participants may have faced difficulties due to different weather conditions to traveling to the facility. Studies implementing longer intervention length of a minimum of 12 weeks could provide better effect of exergaming on PL domains and following-up after six months would verify that the improvements were longer sustained. The impact of weather shouldn’t be ignored when planning strategies for increasing PL levels among older adults, especially for those who are unfit.

With the recent widespread attention in academia of PL philosophical underpinnings, there have been many references to its practice implications (Edwards et al., 2017; Sum, Li, Choi, Huang, & Ma, 2020). To date, valid and reliable assessments that combine the four PL domains in one instrument are only available for children and youth (Kaioglou & Venetsanou, 2020). In the current study, the assessment of the four PL domains as separate was chosen according to recommendations from Edwards et al. (2017). The acknowledgement of PL philosophical foundations remains important. However, a pragmatic perspective reflecting whether individuals are making progress along their PL journey enables researchers and practitioners to operationalize the PL...
constructs and establish measurable differences in specific populations (Edwards et al., 2017).

It is important to note that the equipment used in the study, such as the Nintendo Wii Fit and Fitbit Flex 2 are consumer technologies. Despite previous research suggesting that exergames are safe and feasible for older adults (Fang et al., 2020), the exergame console used in this study was not primarily designed to target fitness or clinical results. The non-customization of the games design to older populations may be challenging in terms of adopting technology to engage in PA. Moreover, while selecting the wrist worn device followed the literature recommendations (Weisberg et al., 2020), this was not the gold standard measurement of daily exertion behaviour in terms of data loss, accuracy, and wear location. Despite lack of evidence of the effectiveness of the exercise programs on daily exertion behaviour, as measured by Fitbits, such devices could be useful to enhance knowledge about PA, and increase awareness of level of individualized activities. The findings from this study could inform technology developers and healthcare providers about designing exercise training programs and user-friendly equipment for older adults.

4.7 Conclusion

An exergame-based training program was feasible in improving and maintaining physical and affective PL domains in community-dwelling older adults. These findings suggest that using exergames and fitness trackers as additional tools for older adults’ PL development may be appropriate. Future studies should investigate how exergames help in achieving long-term healthier exertion behaviours and preventing health disorders of older adults.
Chapter Five: Older Adults’ Perceptions of the Usefulness of Technology for Engaging in Physical Activity: Using Focus Groups to Explore Physical Literacy

5.1 Abstract:

Background: Insufficient physical activity (PA) levels observed among older adults remain extremely high and pose a danger to developing and maintaining their physical literacy (PL). Each person’s level of PL partly depends on their physical and cognitive skills, confidence level, and degree of motivation to practice PA daily. New technologies, such as exergames and wearable fitness trackers, may enable older adults to increase their PL, stimulating uptake and ongoing PA participation. Objective: This focus group study aims to describe older adults’ perceptions of the use of technologies to engage in physical exercise programs. Methods: Fifteen participants were randomly selected from a sample of 40 older adults who completed a randomized controlled trial that investigated the benefits of using technology in the context of group-based exercise programs. Separate post-intervention focus groups were performed with: an exergaming group; a conventional physical training group; and no training group (control). Data were mapped onto constructs from the four components of PL: motivation and confidence, physical competence, knowledge and understanding, and engagement in PA for life. Results: Generally, participants expressed positive perceptions about the benefits of using technology to engage in PA. These positive feelings outweighed the costs and the lack of familiarization with technology. Common themes for the three groups emerged from the discussions and included: familiarization with technology, using fitness tracker to monitor PA, previous exposure to technology, and interaction with peers, staff members, and relatives. In
particular, participants from the exergaming group explored the ideas of training their
cognitive skills while using the exergames accessories, exercising in an alternative way,
competitive versus cooperative play, changes in sense of humor, skill transferability from
game to real environment, progressions of the exercise intensities, and the potential use of
exergames for rehabilitation. Conclusions: Participants in this study reported positive
perceptions about implementing technology into exercise. Emphasizing the benefits of
using technology in group-based exercise programs may increase older adults’ PL levels
and their future technology adoption. The potential implementation of technology into
conventional exercise programs should focus on older adults’ lifelong values,
biopsychosocial conditions, and the possibility of reducing age-related risk of injuries and
chronic diseases.

Keywords: physical literacy; technology; active videogame; elderly; focus groups

5.2 Introduction

According to the United Nations’ report (2019), the proportion of people aged 65
and over is growing faster than any other age group worldwide. Following the same trend,
the rate of technological development has also steadily increased. Advances in technology
in health care and changes in older adults’ lifestyles have led to reductions in mortality and
increases in life expectancy (Clair & Allman, 2018). With the progressively changing
demographics, technology use amongst the elderly is an important research consideration.

The aging effects on health behaviour, such as a sedentary lifestyle, strongly
influence how older adults perceive and experience their surrounding environment (Bonder
& Dal Bello-Haas, 2017). The availability of resources and accessibility to attractive and
safe environments can facilitate physical activity (PA) engagement by older adults
(Lavieri, Dai, & Bhat, 2018). However, only 10–30% of older adults report engaging in regular physical exercise as recommended by validated PA guidelines (Hallal et al., 2012; Sun et al., 2013). The prevalence of sedentary lifestyles poses a danger to maintaining physical and cognitive functions, especially when considering older adults’ age-related vulnerabilities.

Identifying key determinants of an active lifestyle and how these determinants can be promoted is central to successful healthy aging (Smith, 2019). Previous research has shown that the combination of physical exercise with cognitively challenging tasks provided by technology-based exercise programs can improve global physical and cognitive functions in healthy and clinical populations of older adults, compared to physical exercise training alone (Larsen et al., 2013; Stanmore et al., 2017; Zeng et al., 2017). Researchers have examined possible innovative alternatives for PA promotion, including mobile phone applications (Hosseinpour & Terlutter, 2019), wearable and smart home activity sensors (Reeder, Chung, Lyden, Winters, & Jankowski, 2020), and use of active video games or exergames (Gallo, Toro, & Zuluaga, 2016; Sheehan & Katz, 2010). These relatively new technological tools have the potential to be an effective alternative to fulfill sedentary leisure time and enhance older adults’ perceptions of competence, motivation, and confidence to engage in PA (Bice, Ball, Adkins, & Ramsey, 2016; Compernolle, De Cocker, Cardon, De Bourdeaudhuij, & Van Dyck, 2019; Mugueta-Aguinaga & Garcia-Zapirain, 2019). An appropriate implementation of technology based on a well-established theoretical framework may promote successful technology adoption by older adults (Ehlers & Fanning, 2019; Lee, Ajisafe, Vo, & Xie, 2019).
As a promising strategy to achieve lifelong participation in PA, physical literacy (PL) could be a meaningful approach to reducing sedentary behaviours and prevent associated chronic diseases (Jones et al., 2018). PL concept include four main domains to value and take responsibility for engagement in physical activities for life (Whitehead, 2014b). The four PL domains are listed as:

1) Affective – motivation and confidence;
2) Physical – physical competence;
3) Cognitive – knowledge and understanding about PA; and
4) Behavioural – Daily PA habits

The holistic nature of the PL concept also provides the basis for understanding older adults’ technology adoption and perceptions of its use to engage in PA.

5.2.1 Objective

Based on the four PL domains, this study aims to examine older adults’ perceptions of the use of wearable and exergame technologies to engage in physical exercise programs.

5.3 Materials and Methods

5.3.1 Study Design

A focus group approach was used to collect perceptions from three groups of participants in a broader research study designed to increase the PL levels of older adults. The research was conducted in a community facility located in Calgary, Canada from August to December 2018. The study was approved by the Conjoint Health Research Ethics Board, University of Calgary, under the reference protocol number REB16-1633. An interpretive description methodological approach was used to guide data collection, analysis, and presentation of results (Thorne, 2016). Data were mapped onto constructs
from the four domains of the PL consensus statement: cognitive, affective, behavioural, and physical (Tremblay et al., 2018).

5.3.2 Sample and Setting

As part of a larger, randomized controlled trial, 40 older adults were recruited from community and independent-living centers, and randomly allocated to one of the three study groups: Exergame Training (ET, n=15), Conventional Training (CT, n=14), and No Training (NT, n=11). Inclusion criteria for eligible participants were:

- participants aged 65 years and over;
- able to ambulate independently without an assistive device; able to adequately see and hear to interact with the game;
- able to read and speak English to follow instructions.

Participants were excluded from the study if they:

- failed to clear the cognitive test: Mini-Cog Test, score < 3 (Borson, Scanlan, Chen, & Ganguli, 2003);
- presented with an active acute/chronic disease process: Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Warburton, Bredin, Jamnik, & Gledhill, 2011);
- took part in a PA program within three months before the study started;
- were diagnosed with a balance or neurological disorder that seriously affected motor function (e.g., stroke, traumatic brain injury, spinal cord injury, nerve injury, Multiple Sclerosis, or Parkinsonism).
All participants wore a Fitbit Flex 2™ (Fitbit Inc., San Francisco, United States) for the duration of the study. Participants did not have access to the data from the Fitbit until the end of the study. CT and ET groups downloaded the Fitbit data once a week before training. The participants in the NT group were asked to commute to the community facility once a week to meet with the researchers to download the Fitbit data, but did not have contact with the other groups. They did not engage in any exercise training and were advised to maintain their usual daily routine.

Both the ET and CT programs were supervised by a physiotherapist and an assistant. Participants in the ET group used the Nintendo Wii-U and its accessories, such as the Wii Remote and Wii Balance Board to perform the exercise program with the Wii Fit-U sub-games. The CT program consisted of exercises done seated on or standing behind a chair and laying down on an exercise mat. Participants from both exercise groups were asked to attend every session conducted three times a week for six weeks. In case of attendance lower than 75% of the total of the sessions (13 out of 18 sessions), participant’s data would be excluded.

ET and CT participants were divided into three groups each (six groups total) with approximately five participants in each group. In the facility, two similar exercise rooms were used with three time periods, two in the morning and one in the afternoon, so that training was matched for time and group size.

Within one week of the end of the intervention period, six participants from each group were randomly selected and invited to participate in focus group interview sessions. Separate post-intervention focus groups were performed with each study group.
Participants signed a consent form agreeing to participate and allowing the moderators to audiotape the conversations (APPENDIX R).

The principal investigators created an open-ended, semi-structured interview guide (APPENDIX S). The topic guide for all the three focus group interviews included a guiding question and prompts in the following areas:

- General impressions about the study – “Please describe your overall experience throughout this program.”
- Using technology for PA engagement – “Do you think that technology can help you to be more active?”
- Physical Literacy perception – “After describing Whitehead’s definition of PL, do you think that your PL level has changed throughout the study (last six weeks)?”
- Future Technology adoption – “Would you be interested in continuing to use technology in your physical activities in the future?”

5.3.3 Trustworthiness and Data Analysis

The focus group sessions were led by a trained moderator assisted by a note-taking assistant, who did not participate in the exercise programs. The moderator and assistant had access to the open-ended, semi-structured interview guide previous to the focus groups interviews, and were able to clarify doubts and make suggestions to improve the guiding questions and prompts. Refreshments were served to compensate the participants for their time.
Immediately after each focus group, the moderator and assistant discussed the group dynamics, noting common themes and unexpected items. The audiotapes were transcribed verbatim and the transcriptions were checked for accuracy against original recordings. All participant identifiers were replaced by a study code to protect their confidentiality. Transcripts and research field notes were the data products used for analysis.

Interpretive description methodology (Thorne, 2016) with analytic procedures of thematic analysis (Braun, Clarke, & Weate, 2016) were applied to the three focus group transcripts and field notes. The process of codification was mixed: deductive and inductive. It was deductive as the main themes were coded, categorized, and mapped according to the four PL domains. However, due to the genuine interest in the raw data to reveal possible new main themes, the inductive approach was also applied.

For the inductive approach, two independent researchers coded the three transcriptions and field notes in order to find new emerged themes and their subthemes. Then, the research team met in a group to review discrepancies, resolving differences by in-depth discussion, and negotiated consensus. The research team agreed upon application of the final themes and subthemes (Bradley, Curry, & Devers, 2007). The agreed main themes and their subthemes were uploaded to NVivo12 software (QSR International, Doncaster, Australia). The software allowed the researchers to organize the data and tabulate participants’ references by theme. The emerged themes and subthemes are presented in the results section through the interpretation of participants’ own descriptions of their experiences.
5.4. Results

Focus group sessions lasted an average of 38 min (ET: 59min, CT: 31min, NT: 24min). Of the eighteen invited, fifteen participants (ET, n=6; CT, n=4; NT, n=5) attended the post-intervention focus group interviews. Three participants (CT, n=2; NT, n=1) did not show up for their focus group session. Two gave no reason and one had the wrong day in his calendar.

Ten focus group participants (ET, n=3; CT, n=3; NT, n=4) identified as female (66.6%), representing 37% (N=27) of female participants in the main study. The average age of the focus group participants was 73.53 years (ranging from 65 to 85 years), compared to 72.6 years (ranging from 65 to 95 years) from the main study. Participants reported being independent community-dwelling older adults and two of them (CT, n=1; NT, n=1) were residents in an independent-living facility.

5.4.1 Themes: Physical Literacy Domains

Focus groups provided a rich dataset, illuminating older adults’ perceptions of the use of technologies to engage in the physical exercise programs. As recommended by Smithson (2000), individual opinions were not treated as belonging to individuals within the group, nor as held by the whole group, but as constructed discourses that emerged in social and dynamic conversations. The four core elements to understand the experience of older adults were taken from the holistic PL domains, including affective, physical, cognitive, and behavioural. In addition to the well-established PL domains, the inductive approach yielded the social/economic domain as a main theme, given its importance as a determinant of health behaviour (Edwards et al., 2018). Thirty-six subthemes were linked among the overarching umbrella themes and are presented in Figure 5.1.
As depicted in Figure 5.1, the cognitive domain was influenced by eight subthemes that centered on participants’ cognitive capacities to understand and interact with the technologies used to engage in PA. The subthemes shared by the three groups included familiarization with technology and using a Fitbit to monitor PA. Despite being a shared subtheme between the three groups, participants demonstrated different levels of familiarization with technology. For example, P3 (male, 66) from the ET group reported: “This study introduced me to technologies that I’ve never even heard or seen before.” P2 (ET, female, 72) presented her frustrations when previously trying to engage in PA using an exergame device: “I was involved with technology since I was young… So, I thought I
knew all these things. Well, I bought a Sony [active videogame] because I wanted to get fit and it has a fitness program. But I didn’t know how to use it. I used it for about a day and gave up.” In the meantime, P11 (NT, female, 73) demonstrated more familiarity with technology: “I already had a Fitbit. I was afraid that it could interfere with yours, but it didn’t at all.”

The subtheme named knowledge and understanding of PA benefits was shared between participants from the CT and NT groups. P7 (CT, male, 73) mentioned: “When I was young, there was nobody who taught us: ‘oh, you should be exercising three times a week.’ Just hearing about your study with technology already makes a big difference.” P8 (CT, female, 70) commented on her perceptions in regards to the feedback provided by the Fitbit: “It showed me what I was doing and, you know, what [parameters] I need to improve a little bit more.” Meanwhile, the participants from the NT group expressed their curiosity about the exergame training: “Do you have different expectations according to the age of the participant?” (P12, NT, female, 72).

Participants from the ET group further explored the ideas of training their cognitive skills while interacting with the exergames. For example, P4 (ET, female, 66) described her experiences while playing a dual-task game: “Several times I was like, ‘okay, I’ve got to remember to always look on that top one [bar].’ Because if I was only working on the one below, I learned that my score went down. It was probably good for my brain.”

5.4.3 Affective Domain

The affective domain was reflected by the participants’ perceptions of their confidence, motivation, and enjoyment in relation to their technology adoption to engage in PA. For example, P10 (CT, female, 73) stated: “I have got a Fitbit and that got me
motivated because I could see my [number of] steps and it challenged me a lot.”, and “I think it [Fitbit feedback] really makes you feel better about yourself.” P6 (ET, male, 65) shared his perceptions after engaging in the exergaming program: “I think it was great. I am disappointed it’s coming to an end, but it really got me motivated again.” He continued: “So, I’m really glad for the luck that I got in the Wii group because it was way more fun than standing over there doing exercises, you know, seriously.”

Participants who engaged in the exergame training discussed the role of competitive versus cooperative play on their experiences. For example, P3 (ET, male, 66) mentioned: “There was some level of competition between us. It was fun though. I also had fun when we had a common goal and it was that tunnel”, referring to the game in which the participants were asked to statically walk on the balance board, lifting their feet in order to mimic the motions of pedaling a bicycle. P4 (ET, female, 66) replied: “Well, it was a supportive competitiveness.” The discussion continued with P2 (ET, female, 72) expressing her point of view: “It’s a bit of competitiveness with yourself. You know, when I did this the last time, I was like, ‘oh, I got to another level.’ I felt good.”

In addition, participants in the ET group were grateful for being able to participate in the study, identified a change in their sense of humor, and wished that the participants from the other groups could have had the same experience: “We [participants from ET group] sort of ended up melding in our sense of humor with a bit of competitiveness sometimes. The control group is probably disappointed.” (P4, ET, female, 66).

5.4.4 Behavioural Domain

The analysis of the behavioural domain showed that participants from the three groups were able to compare their previous exposure to technology with the current
experience. P11 (NT, female, 73) mentioned that she had a fitness tracker device before starting the study: “I had a Fitbit before. So, I could set a goal of two hundred steps every hour between seven a.m. and seven p.m. If I didn’t complete them, it would giggle and tell me I’ve got to get up and exercise. I couldn’t do the same [setting] with yours [Fitbit].” In addition, P7 (CT, male, 73) mentioned: “I used to be active a number of years ago and the last few years I just haven’t been. So, it was a great chance to participate, get more familiar with the Fitbit, and sort of moving forward from being sedentary.”

Participants from both exercise training groups presented a higher sense of commitment to wear and charge their Fitbit while attending the sessions three times a week, compared to NT group. For example, P5 (ET, female, 75) mentioned: “I never took it off, except to recharge it.” P8 (CT, female, 70) also stated: “It [The Fitbit] kept me engaged in the study. Like, I felt the responsibility to recharge it and come to the sessions. If you volunteer for the study, you feel the responsibility to do it. It’s like you’ve paid for a device or for a fitness class. So, you want to get your money’s worth.” One of her peers (P9, CT, female, 72) agreed: “Yes, when I paid for a trainer, I found lots of reasons not to go and I still ended up paying for it. I’ve never paid for this [study] and I never missed a single session.” However, the majority of the participants from NT group agreed that they forgot to recharge the Fitbit often. P13 (NT, male, 73) tried to justify why he forgot to recharge his device: “Half of the time I forgot the thing [Fitbit] was there. I think it is because we didn’t have access to our accounts, and we had to come only once a week. There was nobody to remind us [about recharging the device]. So, as a result, we didn’t charge it when we should have done so.”
ET participants, in particular, expressed their perceptions of trying a new way of exercising. P1 (ET, male, 73) reported: “I like the variety of them [Wii Fit-U sub-games]. I could tell my body was using different muscles. When you’re not doing anything, you think ‘they are all right’. Then, you use them and you think ‘oh, that’s a new muscle’.” P5 (ET, female, 75) hypothesized: “I loved the Wii. If I had one, I could just sit it in front of the T.V. and sometimes I would flip the switch to exercise.”

5.4.5 Social/Economic Domain

As for the social/economic domain, participants from the three groups shared similar perceptions about the interaction with their peers, staff members, and relatives during the study. Participants from the intervention groups enjoyed exercising with their peers. However, participants from the ET group perceived that their interactions were more related to socializing while playing the exergames. For example, P2 (ET, female, 72) stated: “I never missed one of these sessions at all. A lot of it was because of the people, to be honest with you.” P1 (ET, male, 73) engaged in the conversation and continued: “It was more than just the exercise that we were doing. It was the people that we were working with. The staff members were just incredibly great to have in the room, because they were always supportive and they were always there for us.” Participants from the ET group spoke about their attitudes towards playing exergames with their grandchildren. P4 (ET, female, 66) mentioned: “One [participant] of our group is going to buy one [Nintendo Wii-U]. Her nephew has one and he suggested to her to buy it. So, it’s another way to interact with our grandchildren.” Participants from the CT and NT groups demonstrated their gratitude for the support given by the staff members in regard to issues with their fitness.
trackers. They also revealed that they sought help from their relatives with the placement of the device.

The cost to purchase the equipment used in the study was a shared subtheme that emerged from the conversations between participants that engaged in both exercise programs. Participants focused on their perceptions of the cost-benefit ratio. P1 (ET, male, 73) summarized: “I might consider even buying one [Nintendo Wii-U]. It doesn’t matter its cost.”

The subtheme named willingness to try new technologies was brought up by the participants from the NT group. Based on the comments, participants who did not engage in any of the exercise training seemed willing to try the exergames. Moreover, they appreciated the caring context in which the study was offered.

5.4.6 Physical Domain

In the physical domain, participants from the CT group expressed their perceptions about using technology to monitor their physical competencies, such as their heart rate and number of steps. P8 (CT, female, 70) who owned her own Fitbit, commented on how the device was helpful to her: “Because I’ve got a really low heart rate, I’ve got to move more. So, the Fitbit really helps me to monitor these things, like my BPMs [beats per minute], number of steps, and so on.”

Participants from the ET group presented different perceptions about their experiences using the Wii Balance Board. For example, P3 (ET, male, 66) and P4 (ET, female, 66) shared their frustrations while using the exergame accessory: “Last Friday, we had two boards that were almost dead on battery. They just were not working properly. It was just really a frustrating day for some of us.”(P3); “I felt bad because I got to a new
level on that game on Wednesday, but when I tried it again on Friday, I couldn’t get closer [to the same level]. That’s why I was frustrated.”(P4). In addition, P1 (ET, male, 73) stated: “The board’s malfunction was the only complaint, and that’s not your guys’ fault. You don’t build those boards, and I don’t think they were that great.”

Participants from the ET group discussed their previous experiences engaging in conventional exercise training as opposed to the exergame training. P1 (ET, male, 73) shared his perspective: “When I was paying a trainer to do the job, part of the benefit was because I was being taught a proper form. [Trainer’s name] was always on me to do it properly. That’s one thing you don’t get with the Wii. I mean, if [staff members’ names] weren’t here correcting our forms, I wouldn’t correct it myself.”

The idea of skill transferability from the game to the real environment was another subtheme that emerged from discussions between the participants of the ET group. P4 (ET, female, 66) shared her perspective about the meaning of the scores provided by the exergames: “I had to keep reminding myself that getting a higher score didn’t mean I was getting fitter. It meant I was getting better at the game. So, I had to really remind myself of it.” One of her peers (P5, ET, female, 75) disagreed and stated: “I think you could be getting fitter.” P4 (ET, female, 76) replied, “I could be getting fitter, but that’s not really the feedback from the game. The feedback was that I was getting better at the game. And that may be part of its seduction. It lets you think you’re getting fitter because you’re getting better at the game. So, I’m not saying that’s a bad thing, but I had to be realistic of the fact that this really wasn’t an indication that I was getting fitter.” P2 (ET, female, 72) was more specific and described her experience when balancing on the Wii Balance Board: “I thought I was very well balanced because I have been skiing for fifty-nine years. I’m
still skiing, and I don’t fall or anything. So, when I tried to stand on one foot, it was just like, ‘I don’t ski on one foot’. So, for me it’s been a bit challenging.”

Participants from the ET group were able to perceive different skill levels according to the games’ task and the simulated environments where they performed their training. “I could do the super hula hoop. For me, that was a piece of cake. But, for other people in the group, you know, I just drove a couple of them crazy. They just couldn’t do it. Then, I couldn’t get the ski or the bird games. But they would get them. So, yeah, I could be really good at one exercise but not at another ones.”

Participants from the ET group also discussed their perceptions about the exercise intensity, its progression during the six-week programs, and its potential use for their physical rehabilitation. P2 (ET, female, 72) described her perceptions of the exercise intensity: “The activities were short, but they were intense.” P4 (ET, female, 76) elaborated her thoughts about the exercise intensity relating to the progression of the difficulty in one of the games: “It’s not as hard as the workout that I do in the gym, in terms of heart and respiration rate. But, near the end, I couldn’t repeat [the game] three times. If I did three, I felt that I was working out somewhat near maximum [exertion].” Another participant (P6, ET, male, 65), who had a knee replacement, mentioned his perspective of the potential use of the exergames for his physical rehabilitation: “I had to get my knees replaced two years ago. So, I’m not supposed to run. But on that activity [running on the spot], I’m not really running. I’m not putting a lot of pressure on my knees and I felt great. I will ask my physio to include these [activities] in my therapy.”
5.5 Discussion

This qualitative study explored older adults’ perceptions of using technologies, such as exergames and fitness trackers to engage in physical exercise programs. The focus groups’ analysis was primarily guided by an interpretive description of older adults’ perceptions under the PL theoretical framework. This methodological approach was initially developed for clinical contexts, however in the study described in this article, the participants were physically independent and did not present any functional impairments. Here, each main theme is discussed from the standpoint of how technology may be utilized to promote lifelong PA engagement and its potential use in the prevention and rehabilitation of a variety of diseases.

From a holistic perspective, Whitehead (2010b) proposed that PL encompasses more than a motor action. A physically literate individual should not only be able to ‘do’ a PA, but also be able to ‘read’ the environment and respond appropriately. The ‘reader’ relies on a range of cognitive skills as it resonates with previous knowledge and experience (Whitehead, 2010b). According to the International Physical Literacy Association (IPLA, 2015, p.2) “knowledge and understanding includes the ability to identify and express the essential qualities that influence movement, understand the health benefits of an active lifestyle, and appreciate appropriate safety features associated with PA in a variety of settings and physical environments”. In the present study, the cognitive theme and subthemes were related to the cognitive learning in relation to the technologies used by the participants. Such technological tools used in the current study were perceived to be able to quantify and provide feedback on participants’ PA performance, which assisted them with ‘reading’ their surrounding environment.
Individuals exchange knowledge, experiences, values, and beliefs in constant adaptation to the environment in which they are living. Many older adults are not comfortable with technologies, therefore adoption may be a challenge (Craig & Shelton, 2008; Lee et al., 2019). Moreover, only 36% of older adults are aware of the PA recommendations (Cheung, Talley, McMahon, Schorr, & Wyman, 2019). Providing knowledge and understanding about the importance of PA for a healthy lifestyle, the need to be physically literate, and the role of new technologies in facilitating PA and PL can reduce the barriers to PA engagement.

Familiarization with new technologies is fundamental and influences the success of implementation to engage in PA programs. Research has indicated that, despite becoming increasingly familiar with technology, older adults generally have different abilities and competencies compared to their younger counterparts (Mckee, Matlabi, & Parker, 2012; Uei, Tsai, & Yang, 2013). The relatively recent development and widespread use of wearables and exergames may account for this disparity in abilities and comfort. Findings from the three focus groups demonstrated that the participants presented different levels of familiarization with the technologies used in the study. However, Loew, et al. (2016) stated that the level of knowledge does not necessarily translate into long-term adherence in PA engagement.

Researchers have investigated the factors that employ a strong influence in older adults’ attitudes towards and adherence to the use of technology to engage in PA. Matz-Costa, Carr, McNamara, and James (2016) demonstrated that the affective characteristics that are developed across the lifespan, such as the perceived feelings of enjoyment and satisfaction from previous experiences, the control over exercise, personality, and
psychological health better predict higher levels of PA adherence. According to the self-determination theory supporters (Ryan & Deci, 2017), the intrinsic and extrinsic motivations have a significant impact on individuals’ attitudes towards PA engagement. Intrinsic motivation involves participating in an activity for the enjoyment and satisfaction inherent in engaging in continued behaviour. In contrast, external motivation is a state in which individuals’ behaviour is controlled by specific external factors (Ryan & Deci, 2017). Several studies indicate that individuals who exhibited self-determined types of regulation show more persistence in PA engagement (Rodrigues, Neiva, Teixeira, Cid, & Monteiro, 2019), exercise adherence (Lyu & Zhang, 2019), PA intentions (Jeemin Kim, Eys, Robertson-Wilson, Dunn, & Rellinger, 2019), and enjoyment of physical exercise (Dattilo et al., 2015). Participants in the current study reported that wearing the Fitbit and playing exergames were enjoyable experiences and expressed their wishes to continue the exercise programs. In particular, participants from both exercise groups identified intrinsic and extrinsic motivators to engage in PA. Intrinsic motivators included the wish to get fitter and reduce functional impairments, intentions to learn how to use the Fitbit and how to play the games, paying attention in certain parts of the game, sense of humor, and self-confidence. Extrinsic motivators included the cost and portability of the equipment, access and feedback from Fitbit parameters, sense of improvement, interaction with family, peers, and staff members, competition/cooperation between peers, variability of activities, game scores, and perception of exercise intensity. In contrast, participants also identified external factors that had influenced their lack of motivation or commitment. For example, participants in the NT group justified the reasons for forgetting to recharge their Fitbit with the fact that they were not engaged in an exercise program. ET group participants
expressed their frustration with the technical issues, such as machines not working properly. These findings suggest that structured exposure to new technologies and experiencing the health benefits may be helpful in motivating initial involvement and future adherence to a regular PA program.

Gothe (2018) showed that self-efficacy and outcome expectations are the most consistent affective mediators to change exercise behaviour in older adults. The development of self-efficacy is related to individuals’ self-confidence and their personal choices. As people age, their self-efficacy represents their belief in the capacity to trust and exert control over their lives. In contrast, a lack of confidence in physical abilities and fear of injuries are strong predictors of PA avoidance (Rosic, Milston, Richards, & Dey, 2019). Participants from the current study expressed that they felt good about themselves after engaging in the exercise programs using the technologies and none of them had falls or injuries during the exercise sessions. Participants who did not engage in any of the exercise training demonstrated their willingness to try the exergames. Despite the positive perceptions towards technology in the current study, health professionals must assess older adults’ self-confidence to adopt technologies. Providing cautious fall prevention procedures, and emphasizing perceived confidence and benefits to exercise may encourage older adults to engage in effective PA and accommodate their technology skills.

Whitehead (2010b) considers that psychological factors such as the cognitive and affective domains to be the precursors to the physical and behavioural domains. By recognizing the role of cognitive and affective capabilities, Whitehead (2010b) acknowledges the role of interacting with the social and physical surroundings. Boyle et al. (2019) further state that the affective values arise from the interaction with others and the
response to situations in which the individuals find themselves. Recently, Warner and French (2018) demonstrated that older adults with high self-efficacy levels are more likely to interact socially, which in turn can facilitate the development of their physical competence within a wide range of environments. It has been suggested that older adults with high self-efficacy are less socially anxious and more likely to use technology in general (Mitzner et al., 2010). Thus, adopting technologies may help older adults remain active and socially involved.

The social interaction provided by group-based exercise programs prove beneficial for older adults to overcome psychosocial conditions, such as loneliness, depression, and low self-esteem (Hwang, Wang, Siever, Medico, & Jones, 2019). Moreover, studies show that there is a strong correlation between the use of exergames and positive mood among older adults living independently (Hensley, 2019). The participants from the current study demonstrate that they enjoy interactions with their peers, especially the ones allocated in the ET group who perceive the feelings of competition, cooperation, gratitude, concerns for others, and a change in their sense of humor. Participants also recognize the positive contribution of staff members for their support and identify the feasibility of playing the exergames with their family members, such as their grandchildren. These findings provide support for the implementation of technologies as reliable tools to increase general social interaction.

Theories on the relationship between the accessibility to technology, its regular adoption, and possible cost savings in health care have increased substantially (Thoits et al., 2019). The theory of diffusion of innovations (Rogers, 2010) holds that older adults are less likely to adopt new technologies unless they view the clear benefits of using them. The
technology acceptance model also suggests that older adults may be willing to adopt new technological devices when the usefulness and usability outweigh its costs (Heinz, 2013). By increasing access and reducing costs, technology has the potential to trigger behavioural changes and increase perceived physical competence. The relatively low cost to purchase equipment and a sense of commitment to the study are shared subthemes between participants who engaged in the exercise programs. These findings are consistent with previous studies suggesting that the perception of potential benefits was more indicative of technology acceptance than a perception of cost (Mitzner et al., 2010).

Adopting technology and maintaining regular PA engagement by older adults might be the most important challenge. While older adults may have ceased regular PA engagement or believe they would not be able to partake in PA, participation in such technology-based experiences can give them a sense of involvement in physical exercise and ‘keeping up’ with modern times. Older adults’ behaviours tend to remain in patterns that were perceived as constructive in the past (Amesberger, Finkenzeller, Müller, & Würth, 2019). According to Whitehead (2010b, pp. 161), “Where negative views are repeatedly and forcefully expressed either about the value of physical activity or the embodied competences with which a person is endowed it may be difficult or impossible for participation to continue.” The participants from this study were able to compare their previous exposure to PA and technology with the current experiences. Despite the positive attitude and willingness to adopt technology in the future, participants also demonstrate their frustrations with previous and current experiences. Therefore, mitigating negative experiences by providing technology maintenance and formal training may introduce and keep technology into older adults’ lives in an accessible way.
As relatively new technological tools, exergames are increasingly being used as an alternative to conventional rehabilitation-based exercises to improve daily PA levels and increase physical fitness in older adults (Hamilton, Lovarini, McCluskey, Folly de Campos, & Hassett, 2019). Research shows that older adults exposed to exergame training are able to improve a variety of physical functions, such as balance control, cardiorespiratory fitness, and gait speed, among others (Bezerra et al., 2018; Kappen, Mirza-Babaei, & Nacke, 2019). Exergame programs also provide light-intensity exercises and elicit significantly greater energy expenditure when compared with a resting state (Taylor et al., 2012). The transferability of physical performance from simulated to the real environments remains under investigation; however, evidence supports that older adults perceive lower levels of exertion when exergaming compared to the conventional training (Campelo, Donaldson, Sheehan, & Katz, 2015). In the current study, participants from the ET group present different motor skill levels. However, they are to perceive the intensity and difficulty progression of the activities along the six weeks. They also compare their experiences interacting with virtual environments, which simulated real activities and engaged in activities which they had previously perceived that was impossible because of their health conditions. These findings evince the relevance of using technology-based interventions for PA promotion, leisure-time entertainment, and physical rehabilitation of older adults by motivating them to participate in meaningful activities and maintaining their motor and psychosocial skills.

5.5.1 Considerations and Limitations

Although the participants from the current study enjoyed their PA experiences with new technologies and emphasized the likelihood of using them in the future, the results
should be interpreted with caution, given the possible response bias of participants in the focus group settings and the type of technology used in the study. First, the sample was small and predominantly female (66.6%). As such, the interpretation of overall responses may not apply to males. Amagasa et al. (2017) demonstrated that men tend to decrease leisure-time PA participation as they age, compared to their women peers. Despite that, a gender discrepancy in terms of technology adoption may reflect societal tendencies. Wilson (2003) and Seifert, et al. (2017) found that males are more likely to use or own technological equipment compared to females. Therefore, it is likely that fewer males were considered novices, which could influence the interpretation of their familiarization with technology and future adoption.

Second, the sample included in the current study was considered healthy, independent older adults (average age of 73.53 years). It is important to consider that older adults constitute a diverse group due to their age-related functional declines. There is a possibility that the participants who signed up for the study were already physically active, presenting high motivation and confidence levels prior to engaging in the exercise programs. Thus, considering a larger sample size and further stratification of older adults’ characteristics, such as marriage and employment status, lifestyle, ethnicity, educational achievements, political affiliation, and physical-psychosocial impairments could provide new insights about the research question, and potentially mitigate gender and age bias.

Third, a broad range of technologies to aide in PA engagement has been developed, including commercial and customized types of fitness trackers and exergames. It is important to consider that developers of commercial devices usually do not target older adults as their main costumers. The technologies included in this study were selected based
on their pragmatism to answer the research question and on their commercial accessibility. Furthermore, due to the relatively short duration of the exercise program (six weeks), the participants might have more positive perceptions because of the novel stimulus. Thus, the findings from this study may be used to inform technology developers about older adults’ preferences in order to design devices for this specific population. In addition, practitioners may also adapt commercial technologies and the length of exercise programs thereby increasing the potential for older adults’ acceptance and regular adoption.

Finally, a mixture of a deductive and inductive approach to data analysis aided on the exploration of raw data to reveal the social/economic domain as a main theme. Despite the common application to younger populations, the constructs of PL have recently emerged as a promising strategy to increase lifelong PA participation for older adults (Jones et al., 2018). Current evidence supports the use of the PL concept for older adult focusing on the challenges in increasing their health-related quality of life, achieving recommended PA amount, and continuing their participation in social, economic, and cultural activities (Jones et al., 2018; Edwards et al., 2018, Roetert & Ortega, 2019).

### 5.6 Conclusions

In general, participants presented positive perceptions about implementing technology into their exercise programs. Participants expressed concerns regarding their lack of familiarization with new technologies and socioeconomic factors, such as the accessibility and the cost of the devices. Intrinsic and extrinsic motivators were identified as stimulating uptake and ongoing PA participation.

Based on the positive participants’ perceptions, which outweighed the negative perceptions, emphasizing the perceived benefits of using technology in group-based
exercise programs may be helpful in developing and maintaining older adults’ PL levels, and their likelihood of adopting technology to assist with exercise activities. In addition, mitigating the negative experiences by providing formal training and accessibility to technology may introduce and keep technology into older adults’ lives. The potential implementation of technology to conventional exercise programs should focus on older adults’ lifelong values, their biopsychosocial conditions, and the possibilities of reducing age-related risk of injuries and chronic diseases.

5.7 Funding

Coordination of Improvement of Higher-Level Personnel (CAPES), Government of Brazil, and Sport Technology Research Laboratory (STRL), University of Calgary, Canada, provided financial support for this research project.

5.8 Acknowledgments

Special thanks to Chartwell Retirement Residences for providing space for the exercise trainings; to the participants for engaging in the study; and to STRL members, who aided in data collection.

5.9 Conflicts of Interest

The authors declare no conflict of interest.
Chapter Six: Discussion

6.1 Summary

This thesis aims to provide a novel and significant contribution to PL literature, in which the primary purpose was to develop evidence-based practices on how to effectively implement AVG in exercise programs for older adults’ PL enhancement. To fulfill this objective, a mixed-method approach was selected to answer the three main research questions: “How can active video games be implemented as an effective approach to enhancing older adults’ physical literacy?”; “How does an active video game-based exercise program for older adults affect their physical literacy?”; and “What are participants’ perceptions of the technology-based exercise programs as a way to improve physical literacy?”.

In chapter two, a review of pertinent literature was presented. At the end of 20th century, PL concepts have emerged as promising to frame long-term active lifestyles. With recent increased acceptance of PL concepts, many PE programs have moved from teaching sports, games, and activities to teaching skills that are needed to participate in lifetime sports, games and activities (Telford et al., 2020). Despite the lack of longitudinal research, PL programs have demonstrated that children who are more physically active perform better in academics, presenting higher test scores than those who are not active (Telford et al., 2020; Castelli, Hilman, Buck, & Erwin, 2007; Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983). For example, recent investigation by Telford et al. (2020) demonstrated that implementing a PL approach to a 33-week PE program had a positive impact at the student level. The findings demonstrated that the grade 5 students: appreciated the
specialized contributions of the program instructor; appreciated that the lessons were taught by the classroom teacher; enjoyed the implementation of games that included students with different capabilities; developed more confidence to perform the proposed activities without the fear of failure; became more aware that their own improvement on the activities was more important than winning the competition; became more motivated to participate in the proposed activities; enjoyed continuing the activities and games even during school recess times; and appreciated having fun and the opportunity to develop team work skills.

However, studies have shown a lack of focus to implement PL approach to specific older populations’ contexts, such as people with disabilities and older adults’ vulnerabilities (Pushkarenko, Dunn & Wohlers, 2020). Nevertheless, new research efforts are required to better understand PL journey through its philosophical and pragmatically underpinnings from an older adult perspective. The limited evidence on effective methods to improve older adults PL, support the progress of their PL journey, and shows the individual and societal benefits of PL.

The current thesis has captured the volitional nature of PL and the various physical-psychosocial factors that influence it. Potentially, technologies, such as AVG systems and wearable fitness trackers, provide a variety of opportunities for older adults to perform and monitor many forms of PA, reinforcing their PL. The positive effects of such technologies are built mainly on their ability to elicit personal and situational interest, which can be contextualized to individual PL. Appropriate age-specific activities offered by technologies would allow older adults to successfully start or continue the journey along the PL path. AVG would ultimately serve as key stimuli to support participants in continuing their
journey on being physically competent, confident, and motivated movers on a regular basis, and assisting with successful aging. The possibilities offered by AVG to play either alone or with others in the same or separate physical spaces were also discussed. Despite its potential to enhance participation, enjoyment, confidence, desired PA levels, and adherence to PA programs, AVGs have to yet establish their potential to develop older adults PL. From a methodological standpoint, there are gaps on the current AVG literature that still need to be addressed, such as: the duration and content of the programs, which greatly differ from one study to another; larger sample sizes are also needed to evaluate precise estimates of the effects of AVG; several authors have investigated long-term PA program adherence with AVG (Choi, , Guo, Kang & Xiong, 2017), however there is a lack of studies that combine the qualitative and quantitative in a integrative approach, such as the PL concept.

The first manuscript in this thesis, addressed in chapter three, theorized the possibility of and how to use AVG to improve older adults’ PL. Based on the presented evidence of the positive effects of AVG on older adults’ biopsychosocial behaviour, an ecological model was proposed. There is currently a diverse range of theories and measures of PA behaviours, however, this is the first theoretical model that addressed the holistic integration of new technologies to enhance the four PL domains to older adults. The manuscript also addressed possible culturally driven strategies for AVG implementation into exercise programs considering personal and structural factors that would affect PL outcomes. Thus, given the heterogenous preferences of older adults, the proposed ecological model to implement AVG-based exercise program provides a useful framework to create a comprehensive and realistic plan. Healthcare providers who understand the
physical and cognitive needs of older adults recipients could use the model to prescribe an
AVG-based exercise program to fit to their specific needs. In addition, AVG design
process could benefit from inputs by recipients and providers, as they are the final users of
the tools. The promotion, prevention, and rehabilitation processes would be ultimately
enhanced considering the holistic approach to PA provided by the four PL domains. The
scope and potential for realistic use of PL concepts and AVG-based exercise programs
toward active aging still need further investigation.

Chapter four addressed the quantitative part of the research by employing a single-
blinded randomized controlled trial (RCT) involving 40 community-dwelling older adults.
Participants were randomly allocated to one of the three physical exercise training
conditions: AVG training, conventional exercise training, and no training. The exercise
programs were conducted three times a week for six weeks, with the primary objective of
improving functional mobility, daily step count, motivation, confidence, and knowledge
about PA. The quantitative analysis demonstrated that participants in the AVG training
program improved their physical and affective PL domains.

The lack of effectiveness of AVG to the other two PL domains, cognitive and
behaviour, was discussed according to the sample demographics and study design.
Participants were considered physically active previous to the beginning of the proposed
exercise programs. In addition, the exercise programs did not address specific or structured
procedures to increase knowledge and understanding about PA, limiting the expected
effects. Furthermore, the length of six weeks of intervention and three weeks of follow-up
seemed to be too short to produce the expected effect and guarantee its maintenance.
Despite the limitations and lack of positive changes on two of the four PL domains,
learning the quantitative outcomes of an AVG-based exercise program on PL domains can act to “open doors” to an active and healthier journey towards later life. Future research including longer exercise programs’ length, combined with structured education program about PA guidelines and PL concepts, may effectively increase all the four PL domains in older adults.

The qualitative arm of the study was addressed in chapter five. A focus group approach was used to collect RCT participants’ perceptions about their experiences using technologies to engage in PA and how it influenced their PL levels. A total of fifteen participants were randomly selected from the sample of 40 older adults who completed the RCT. The qualitative data were mapped onto the four PL domains, and analyzed under interpretive description and thematic analysis methodologies, accordingly. The inductive approach to analyze the focus groups transcriptions yielded a fifth theme, the social/economic theme. Participants reported their positive perceptions about implementing technology into exercise programs, such as: willingness to try a new form of exercising; enjoyment; confidence; competence; sense of humor; sense of commitment, awareness of PA parameters; body-mind integration; role of socializing with peers in competitive and cooperative play; possible skill transferability from virtual to real environment, possible use of avg for rehabilitation purposes. These positive perceptions outweighed their following negative perceptions: frustrations with equipment malfunction; lack of familiarization; and cost to purchase the equipment used in the study.

This thesis involved developing a theoretical model, quantitatively analyzing part of the model, and providing a qualitative assessment of participants’ experiences. Table 6.1
provides the summary of the quantitative and qualitative findings according to each PL domain and their outcome measures.

<table>
<thead>
<tr>
<th>Physical Literacy Domain</th>
<th>Instrument (Quantitative)</th>
<th>Dependent Variable</th>
<th>Effect of AVG</th>
<th>Perceptions (Qualitative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical (Physical Competence)</td>
<td>Timed Up and Go Test (seconds)</td>
<td>Functional Mobility</td>
<td>Increased</td>
<td>Better Balance; Possible Skill Transferability; Higher Exercise Intensity.</td>
</tr>
<tr>
<td>Affective (Confidence and Motivation)</td>
<td>Exercise Confidence Survey (Total Scale Score); Motives for Physical Activity Questionnaire-Revised (Total Scale and Subscales Scores)</td>
<td>Confidence to Exercise Motivation to Exercise</td>
<td>No Change</td>
<td>Increased Extrinsic Motivation</td>
</tr>
<tr>
<td>Behavioural (Engagement in Physical Activity for Life)</td>
<td>Daily Step Count (Number of steps)</td>
<td>Daily Step Count</td>
<td>No Change</td>
<td>Sense of Commitment; Comparisons to previous experiences.</td>
</tr>
<tr>
<td>Cognitive (Knowledge and Understanding)</td>
<td>Knowledge and Understanding Questionnaire (Total Scale Score)</td>
<td>Knowledge and Understanding about PA</td>
<td>No Change</td>
<td>Lack of Familiarization; Better Cognitive Skill.</td>
</tr>
<tr>
<td>Social / Economic</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>High Cost; Social Interaction.</td>
</tr>
</tbody>
</table>

Abbreviations: PA – Physical Activity

### 6.2 Implications of the Studies

Operationalizing AVG through a mixed-method approach provided a valuable step to better understand the PL implications for older adults. This thesis offers novel and valuable insights to implement AVG in traditional exercise programs for older adults by theorizing an ecological model and testing part of this model under a mixed-methods approach. The results, combined with evidence from previous studies could help inform how AVG and fitness trackers should be successfully implemented into exercise programs.
to improve older adults’ PL. Considering the primary outcome data and participants’ perceptions, findings from this research suggest that participants improved their functional mobility after engaging in AVG-based exercises and perceived the possibility of transferring their performance from the game to real environments. Moreover, no adverse events were reported, indicating that AVG-based exercises were safe and feasible. Exploring the controlled and safe environments provided by AVG could be a great resource in which to practice more demanding everyday tasks.

Evidence suggests that motivation to engage in various PAs goes beyond health and fitness benefits, in both the exercise and sport domains. AVG seem to make exercise fun, thus motivating older adults to engage in PA. Participants of the current study exhibited their concerns for health and fitness outcomes after AVG intervention. Furthermore, participants reported their perceived enjoyment while exercising with their peers. As such, exploring AVG intrinsic and extrinsic motivators to achieve healthier lifestyles, maintain physical and mental independence while socializing and enjoying the interactive activities may be a practical approach to promote lifelong PA engagement.

One of the challenges of applying technologies as part of an ecological model for older adults’ PL optimization would be overall accessibility. Despite positive outcomes and perceptions about implementing technologies into exercise programs, participants expressed concerns regarding their lack of familiarization with new technologies and socioeconomic factors, such as the accessibility and the cost of the devices. Research has pointed out that healthy lifestyles are not equally accessible to all. Moreover, health maintenance in older ages is not only a matter of making the ‘right’ choices, especially when taking into consideration the potential impact that inequalities experienced across the
life course have in later life (Katz & Calasanti, 2015; Martinson & Berridge, 2015). According to Harbison (2016), accessibility to healthier lifestyles, and technology are often related to educational levels of their populations. Therefore, incorporating PL concepts into multi-level and multidimensional approaches may enable older adults to fully realize their own values and stimulate policymakers to provide realistic opportunities for life-long PA access. Possible public-private partnerships might improve the provision of services, quality, and accessibility to higher education and consequently to technologies into exercise programs. Reformulating educational curriculum, including PL concepts, would also provide early awareness and comprehension of PA’s role in healthy aging, recommended PA guidelines, adaptations for safe participation, and choosing the appropriate technologies to help engage in PA in later life.

Finally, the current study design presents useful implications for designing technologies for older adults’ PA engagement. One of the underlying core concepts of technology design is the initial user research to understand user needs. A mixed-method approach to gathering information about older adults’ context to use technology for PA engagement may include objective measurement, such as surveys and dynamic tests, or subjective observations, such as individual or focus group interviews. Contextual understanding is necessary due to heterogenous characteristic of elderly populations and broader aspects of the surrounding social, economic, and physical environment. Both age-related changes and the built environment impact technology design and the types of technologies that would be considered feasible to address health needs. Therefore, designing technologies to be implemented into contextualize exercise programs for older
adults has the potential to decrease overall age-related functional declines, improving health status and lowering costs for the health care systems.

Future game designers who are interested in building AVG to older adults could also benefit from PL concept. First, physical competence domain will rely on maintenance and improvements of older adults’ functional mobility. Practice should be provided for each movement and activity during each exercise component, warm-up, aerobics, strength, flexibility, balance, and cool-down. AVG-based exercises for each component will not only help the recipients to maintain their functional mobility, but reduce the risk of injuries and facilitate activities of daily living. Second, the difficulty level of the game may be adapted to the current state of the recipients as they might have difficulty in performing certain movements and activities during gameplay. Therefore, matching the difficulty of the game to the current state of the individual would be necessary for recipients to experience and select movements they are comfortable performing before playing the game.

AVG programs should be designed to enable the transfer of the trained skills from virtual to real environments, and for the possible use of AVG for rehabilitation purposes. The transition time between activities or selection of the activities may be based on the recipients’ real-time and their gameplay performance (e.g., game scores). Game time control may be useful to avoid overly intense exercise, which might put the recipient at risk of eliciting unwanted overuse issues. Third, alerts should be provided for games that require balancing on a narrow base of support, avoiding falls. Balance exercises without proper guidance on how to perform them could lead to potentially dangerous situations to the elderly, such as falls.
Proper progression of AVG difficulty levels may aide on the affective PL domain. Level of difficulty plays a big role in keeping players motivated and encourages self-confidence when performing the activities. According to the findings in the current study, games focusing on the extrinsic motivation (e.g., external reward, such as becoming healthier and fitter) may be preferred when designing games for older adults. Given the participants’ lack of familiarization with technologies and their willingness to try a new form of exercising, the scenarios, characters, and music may be selected to evoking emotions and personal memories, keeping recipients engaged with the program.

Designers may rely on the positive perceptions regarding the benefits of exercise programs, contributing as a factor for continued PA, as part of the behavioural PL domain. In addition, positive social interaction may be important in the prediction of continued PA among older adults. Thus, multi-player exergaming and group-based exergaming may increase adherence, leading to PL maintenance.

Designing AVG that include information regarding physical and health literacy may address the cognitive PL domain. By reinforcing the notion of self-efficacy regarding lifestyle choices and alternatives to sedentary behaviours, an AVG system may aide in the education of the recipients regarding the underpinnings of PL concept. For instance, the inclusion of a virtual instructor, providing visual demonstrations of exercises and activities, and informing good practices could increase knowledge about all four PL domains.

6.3 Limitations and Future Directions

Despite the theoretical support and promising results, the research presented in this thesis does not come without limitations that warrant further investigation to help build a practical model for AVG use in older adults’ health care. The older adults sample used in
the present study was considered healthy and predisposed to engage in PA, limiting the generalization of the data. Important individual and structural factors, such as presence of comorbid conditions, personal beliefs, education level, previous PA experiences, accessibility to equipment, and availability of exercise programs need to be taken into consideration in future research. Additional research in this area should expand and integrate PL constructs to explore the complex variety of individual and structural factors that influence PL journey. Furthermore, the ability to monitor the PL journey in an accurate and repeatable manner is foundational to both research and knowledge translation. To date, assessments that combine all aspects of PL and that have established validity, objectivity, and reliability have focused on quantitative assessment of children’s physical competencies. Thus, there is a need to develop valid and reliable qualitative and quantitative methods to measure, monitor, and interpret older adults PL, potentially adapted to individual context. Valid and reliable instruments may aide the specificity and sensitivity when assessing ongoing changes in each of the PL domains (physical, affective, cognitive, and behavioural) with a diverse population of older adults. A mixed-method approach presents advantages in exploring different social realities associated with older adults’ emotions, physical and cognitive capabilities, behaviours, and the opportunities provided by the environment to be active and healthy. Study designs involving multicenter data collection may also facilitate the acquisition of larger and stratified sample, and should be also considered in future studies.

In the current study, the implementation of AVG in exercise programs for older adults was framed by aforementioned PL constructs. PL is a relatively new concept that has been mainly applied to children and youth where most part of physical, cognitive,
affective, and behavioural domains are developed. PL conceptual roots on philosophical perspectives of monism, existentialism, and phenomenology support the engagement of regular PA throughout the lifespan. It is important to acknowledge that regular PA engagement is a repeated behaviour and has a high likelihood of being reliably performed in the same context as part of a routine. It is also important to note that a variety of theoretical constructs have been used to understand PA behaviour, such as the social-cognitive theory, theory of planned behaviour, self-determination theory, and transtheoretical model. Such constructs have been modelled and tested among different populations, including older adults, commonly focusing on behaviour change as the ultimate goal for regular PA engagement. However, PL advocates defend the idea that PA is not one simple behaviour but a complex integration of individual determinants developed throughout a contextualized life course. When adopting PL concepts as strategies to increase PA, the improvement and integration of all four PL domains are needed. Elements within each domain support to what degree an older adult is physically literate. Further investigation on individualized contextual factors that contribute to improving PA behaviour and PL outcomes is still needed to understand and address the alignment among PL theory, research, and practice.

Based on IPLA definition of PL, motivation, confidence, physical competence, knowledge, and understanding could be interpreted as the most obvious individual level factors or targets for PL interventions. However, such a statement would be overly simplistic in relation to the complex PL construct. As a relatively new and holistic approach, PL still overlaps established concepts specific to each of its four domains. The current lack of exploration of PL concepts to older adults, and the lack of information on
how to operationalize it including alternative and innovative technological tools, such as AVG, limits the full understanding and acceptance by practitioners and policymakers working in the field of active aging. Future adopters of a practical socio-ecological PL model for older adults must also recognize the heterogeneous characteristics observed across the elderly population and their contexts across the globe. The demands placed on older adults to be active in real-world contexts require physical-psychosocial skills which, in general, is lacking in most older adults. The use of technologies for older adults’ PL enhancement has the potential to be effective, when promoting PA in an innovative way, reducing medical conditions, and improving their overall health. Future research is still needed to elucidate effectiveness in such a large scale.

It is important to note that industrial developments in AVG and fitness trackers technologies have changed and progressed in the last two decades. For example, the video game console used in the present research, Nintendo Wii-U, and the fitness tracker, Fitbit Flex 2 are both successors to their first versions, Nintendo Wii and Fitbit Flex, respectively. Despite increased use of such devices in research settings because of their user-friendly functions and practical implications, both are consumer technologies designed for the general public. With recent advances in consumer technologies and their availability at lowers costs, the main efforts pertain to the adaptations and customizations of such devices to attend to the specific needs of elderly populations. Based in the proposed ecological approach to the use of technologies to improve older adults’ PL, exploring AVG devices and accessories, such as movement tracking cameras and head-mounted displays, which offer naturalistic interactions with virtual objects and environments, would enable quick skill transferability to real situations. In addition,
exploring different types of sensors embedded within fitness tracker devices, such as accelerometers, gyroscopes, magnetometers, barometers, altimeters, and photoplethysmography, optimizing their accuracy and minimizing data loss might enlighten older adults’ PA engagement, according to their preferences and concerns.

The future adoption of new technologies will have a great impact on aging populations and the way that practitioners and researchers care for laboratory and clinical outcomes. The continuous development of technologies and advancements on their relationship to healthy aging are the result of a multidisciplinary approach. Systematic and integrated approaches from researchers, healthcare providers, designers, and clinical patients are needed to advance the implications outside of the laboratory setting. As this innovative field progresses, healthcare providers may need continued training and certification to incorporate technologies into their exercise programs, and to guide their clients through the multitude of available technological options.

6.4 Conclusion

This thesis contributes to the advancement of the application of PL constructs to older adult populations. The implementation of technologies, such as AVG and fitness trackers, as key mediators to assist in the enhancement of biopsychosocial aspects of older adults’ PL journey is acceptable, safe, and a potentially effective approach. As an effort towards operationalizing the potential of new technologies to improve older adults’ PL, a mixed-methods approach was an efficacious way to provide a comprehensive quantitative and qualitative analysis. Based on the findings, older adults who engaged in a six-week AVG training program improved and maintained their functional mobility and extrinsic motivation to become healthier and fitter. Participants also demonstrated their positive
perceptions about implementing technologies into their exercise programs, such as willingness to try a new form of exercising, enjoyment, confidence, competence, sense of humor, sense of commitment, awareness of PA parameters, body-mind integration, role of socializing with peers in competitive cooperative play, and possible skill transferability from virtual to real environment. Such positive perceptions outweighed their negative perceptions of frustrations with equipment malfunction, lack of familiarization and cost to purchase the equipment used in the study. Emphasizing the positive benefits and mitigating negative experiences may be helpful to developing and maintaining older adults’ PL using technologies in group-based exercise programs.

There remains a need to articulate appropriate means of PL assessment based on the holistic and integrated nature of the concept, including the meaningful domains to older adults’ capabilities, their environment, and culture, not just on their physical competencies. From a socio-ecological perspective, tracking and charting progress of sustained PA engagement for life will be valuable for participants at all ages and ability levels. Addressing these gaps will inform future research as well as the development of programs and policies to increase older adults’ PL levels.
References


Fong, M., Moua, A., DeNola, E., & Franklin, M. (2019). The Impact of Fall Efficacy on Occupational Performance in Community-Dwelling Older Adults. Occupational Therapy


consensus process by the collaborative working group on physical literacy for older Canadians. *BMC geriatrics, 18*(1), 13.


APPENDIX A – Certificate of Publication

CERTIFICATE OF PUBLICATION

Certificate of publication for the article titled:
Older Adults’ Perceptions of the Usefulness of Technologies for Engaging in Physical Activity: Using Focus Groups to Explore Physical Literacy

Authored by:
Alexandre Monte Campelo; Larry Katz

Published in:

Basel, July 2020
Dear Dr. Gareth R. Jones,

I am currently writing my PhD thesis entitled “Using Active Video Games to Improve Older Adults’ Physical Literacy: A Mixed Methods Approach”.


The figure to be reproduced is:
I would like to include the figure within the printed examination copy and also the electronic version of my thesis, which will be added to University of Calgary's Digital Repository [https://prism.ucalgary.ca/](https://prism.ucalgary.ca/) and made available to the public under a Creative Commons (Attribution-NonCommercial-NoDerivatives 4.0 International) License.

If you wish to grant me all the permissions requested, please return a signed copy of this letter. If you wish to grant only some of the permissions requested, please list them, and then sign it.

Yours sincerely,

Alexandre Monte Campelo

**Permission granted for the use requested above:**

I confirm that I am the copyright holder of the figure above and hereby give permission to include it in the print and electronic version of your thesis. I understand that the electronic version of the thesis will be made available, via the internet, for non-commercial purposes under the terms of the user licence.

**Name:** Gareth Jones

**Organisation:** formerly with the University of British Columbia (2008-2019), now with the Okanagan Indian Band

**Job title:** formerly Assistant Professor UBC Okanagan, now Director of Education, Language and Culture.

Signed: July 22, 2020
PARTICIPANTS NEEDED FOR RESEARCH IN

Effects of Structured Exercise Programs in Older Adults (65 Years and over)

We are looking for volunteers to take part in a study of Exercise Training Programs including Exergames and general exercise.

You would be asked to complete a screening questionnaire, physical readiness questionnaire and undergo a balance assessment session.

Your participation would involve 18 sessions, each session will be about 30-45 minutes long over 6 weeks.

For more information about this study, or to volunteer for this study, please contact:
Alex M. Campelo
Sports Technology Research Laboratory

This study has been reviewed by, and received ethics clearance by the Conjoint Health Research Ethics Board (CHREB), University of Calgary.
APPENDIX D - Screening Questionnaire

Thank you for working with the Sports Technology Research Laboratory regarding our study on the effects of exercise programs in older adults. The participants will follow a six-week exercise program. During the six-week period, there are three sessions each week. Each session will last 30-45 minutes. If you are interested to participate in this study I would like to ask you few questions to make sure that you fit the criteria. All the data collected will be kept confidential.

1. How did you hear about this study?
   a) Recruitment Poster  b) University of Calgary website  c) Family or Friend  d) Other
2. Name: ______________________________
   ____________________________________
   Age: ______

3. Living Setting:
   a) Independent/Community
   b) Senior Residents
   c) Assisted Living/Nursing Home
   d) Other

4. Do you own or have access to gaming console such as Microsoft X Box / Play Station or Wii Fit?
   Yes  No

5. Do you regularly perform any kind of physical activity?
   Yes  No

6. If “Yes”?
   Explain the type of activity (ies):
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   Total Time per Week: ______
7. Did you participate in any regular physical activity program in last 3 months?
   Yes  No

8. Do you have problems with Balance?
   Yes  No

9. If Yes, have you ever been diagnosed with a balance disorder such as Positional Vertigo, Labyrinthitis, Motion Sickness, Multiple Sclerosis, Parkinsonism or Cancer?
   Yes  No

10. Did you experience any fall in the last year?
    Yes  No

11. If Yes, how many incidence of falls in the past year? ____________

12. How do you rate your balance abilities?
    a) Excellent  b) Good  c) Fair  d) Poor

Can you please provide us your contact details?

13. Postal Address:

14. Email Address:

15. Phone number:

16. What is your preferred method of communication?

We appreciate your time and interest,

Sport Technology Research Lab
APPENDIX E – Mini-Cog Test

Mini-Cog™

Instructions for Administration & Scoring

ID: __________ Date: ________________

Step 1: Three Word Registration

Look directly at person and say, “Please listen carefully. I am going to say three words that I want you to repeat back to me now and try to remember. The words are [select a list of words from the versions below]. Please say them for me now.” If the person is unable to repeat the words after three attempts, move on to Step 2 (clock drawing).

The following and other word lists have been used in one or more clinical studies. For repeated administrations, use of an alternative word list is recommended.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>Leader</td>
<td>Village</td>
<td>River</td>
<td>Captain</td>
<td>Daughter</td>
</tr>
<tr>
<td>Sunrise</td>
<td>Season</td>
<td>Kitchen</td>
<td>Nation</td>
<td>Garden</td>
<td>Heaven</td>
</tr>
<tr>
<td>Chair</td>
<td>Table</td>
<td>Baby</td>
<td>Finger</td>
<td>Picture</td>
<td>Mountain</td>
</tr>
</tbody>
</table>

Step 2: Clock Drawing

Say: “Next, I want you to draw a clock for me. First, put in all of the numbers where they go.” When that is completed, say: “Now, set the hands to 10 past 11.”

Use preprinted circle (see next page) for this exercise. Repeat instructions as needed as this is not a memory test. Move to Step 3 if the clock is not complete within three minutes.

Step 3: Three Word Recall

Ask the person to recall the three words you stated in Step 1. Say: “What were the three words I asked you to remember?” Record the word list version number and the person’s answers below.

Word List Version: ______ Person’s Answers: ____________ ____________ ____________

Scoring

<table>
<thead>
<tr>
<th>Word Recall</th>
<th>0-3 points</th>
<th>1 point for each word spontaneously recalled without cueing.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Clock Draw:</th>
<th>0 or 2 points</th>
<th>Normal clock = 2 points. A normal clock has all numbers placed in the correct sequence and approximately correct position (e.g., 1, 3, 6 and 9 are anchor positions) with no missing or duplicate numbers. Hands are pointing to the 11 and 2 (110). Hand length is not scored.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Total Score:</th>
<th>0-5 points</th>
<th>Total score = Word Recall score + Clock Draw score.</th>
</tr>
</thead>
</table>

A cut point of <3 on the Mini-Cog™ has been validated for dementia screening, but many individuals with clinically meaningful cognitive impairment will score higher. When greater sensitivity is desired, a cut point of <4 is recommended as it may indicate a need for further evaluation of cognitive status.

Mini-Cog™ © S. Borson. All rights reserved. Reprinted with permission of the author solely for clinical and educational purposes. May not be modified or used for commercial, marketing, or research purposes without permission of the author (sborson@andic.com). v.01.19.16
APPENDIX F - Copyright Permission to use Mini-Cog

From: Soo Borson <soo.borson@gmail.com>
Sent: Sunday, November 20, 2016 1:36 PM
To: Jawad Hashim
Subject: Re: Mini-Cog Permission Form

Permission granted. Please acknowledge copyright and permission any any publication resulting from your work.

Best wishes for success!
Soo Borson MD

Sent from my iPhone

> On Nov 20, 2016, at 8:49 AM, Jawad Hashim <jawad.hashim@ucalgary.ca> wrote:
> 
> From: Jawad Hashim <jawad.hashim@ucalgary.ca>
> Institution: University of Calgary
> Country: Canada
> State: 
> 
> Study Title:
> - Effects of Structured Exergaming Curriculum on Postural Balance in Older Adult
> 
> Study Objectives:
> - The objective of this study is to determine if a structured curriculum of exergames in older adults would improve postural balance, confidence in balance and fear of falling when compared to conventional balance training program and controls.
> 
> Source of Funding:
> - Sports Technology Research Laboratory, University of Calgary
> 
> Name of PI:
> - Dr. Larry Katz
> 
> This e-mail was sent from a contact form on Mini-Cog (http://mini-cog.com)
APPENDIX G – Par-Q+ Form

CSEP approved Sept 12 2011 version

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said that you have a heart condition OR high blood pressure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Are you currently taking prescribed medications for a chronic medical condition?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Do you have a bone or joint problem that could be made worse by becoming more physically active?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Has your doctor ever said that you should only do medically supervised physical activity?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- You may take part in a health and fitness appraisal.
- If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist” (CSEP-CEP) or CSEP Certified Personal Trainer” (CSEP-CPT).
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better.
- You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.
## SECTION 2 - CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you have Arthritis, Osteoporosis, or Back Problems?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>1b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylosis/pars defect (a crack in the bony ring on the back of the spinal column)?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>1c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2. Do you have Cancer of any kind?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2b. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3. Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3b. Do you have an irregular heart beat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3c. Do you have chronic heart failure?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3d. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3e. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4a. Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4b. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4c. Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>5. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer’s, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>5a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>5b. Do you also have back problems affecting nerves or muscles?</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Question</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>6. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6c. If asthma, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8b. Do you have any impairment in walking or mobility?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Do you have any other medical condition not listed above or do you live with two chronic conditions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9c. Do you currently live with two chronic conditions?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.
PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a qualified exercise professional (CSEP-CEP) for further information.
- Delay becoming more active if:
  - You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better.
  - You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
  - Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- Please read and sign the declaration below:

  I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designee) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME __________________________________________________________ DATE __________

SIGNATURE ________________________________________________________ WITNESS __________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER __________________________

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. B. Warburton with Drs. Noreen Genaidy, Dr. Veronica Jamarik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

COPYRIGHT © 2012 4/4
CSEP approved Sept 12, 2011 version
APPENDIX H - Consent Form for Subject Screening

TITLE:
The Impact of a Structured Exergaming Curriculum on Physical Literacy and Postural Balance in Older Adults

INVESTIGATORS
Dr. Larry Katz, Professor
University of Calgary - Faculty of Kinesiology -

Mr. Alexandre Monte Campelo, PhD student
University of Calgary - Faculty of Kinesiology -

SPONSORED BY THE SPORT TECHNOLOGY RESEARCH LABORATORY

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information. You will receive a copy of this form.
WHAT IS THE PURPOSE OF THE STUDY?

The overall goal of this research is to improve confidence in movement in different environments, and postural balance status of seniors and mitigate physical impairments risks associated with aging exploring the potential of active video games compared to a regular exercise group.

WHAT WOULD I HAVE TO DO?

At this stage we will gather some initial information regarding your eligibility to participate in this research study. This brief screening interview will comprise of few questions related to your physical activity and balance. After completing the questionnaire you will undergo a balance examination test and a brief test for reasoning skills and memory.

WHAT ARE THE RISKS?

As with any research procedures, there are some associated risks that you should be aware. There is possibility of feeling muscles soreness and tiredness after session. This muscle soreness is a temporary response to the progressively increased physical activity. As a part of the balance assessment you have to perform different tasks which will challenge your postural balance so there is an inherent risk of losing balance.

WILL I BENEFIT IF I TAKE PART?

This study may be beneficial, as the participants will have the opportunity to improve their physical abilities. Participants may also benefit from physical and cognitive performance analysis activities and the increased motivation and understanding towards a more active daily behavior.

DO I HAVE TO PARTICIPATE?

Involvement in this study will be completely voluntary, in which you are free to withdraw from participation in this study at any time without any consequence by simply writing a letter to researchers indicating as such.

WHAT ELSE DOES MY PARTICIPATION INVOLVE?

In this research, personal information that will be collected include name, gender, and physical literacy level however names will not be connected to the data for analysis and presentation of the results. We will videotape the experimental session so that it may be reviewed; the video will be used for research purposes only, given your consent.

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?
You will not be paid for participating and you will not need to pay for anything in this study.

**WILL MY RECORDS BE KEPT PRIVATE?**

All the data collected during this interview will be kept confidential. The interview documentation will be locked in a separate secure cabinets and shall remain in the investigator’s possession or securely locked in a filing cabinet inside the co-investigators office. Final disposition of data will occur in accordance with current guidelines established by the University of Calgary. The research team will make every effort to keep you informed of the progress in the study and if new information or changes to the study are required, you will be informed accordingly.

**IF I SUFFER A RESEARCH-RELATED INJURY, WILL I BE COMPENSATED?**

In the event that you suffer injury as a result of participating in this research, the University of Calgary, the Calgary Health Region and/or the Researchers will provide no compensation to you. Although, the researchers will make every effort to provide you a comfortable and safe environment while your participation. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

**SIGNATURES**

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardizing your health care. If you have further questions concerning matters related to this research, please contact:

Dr. Larry Katz Or Mr. Alexandre Monte Campelo

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary.

<table>
<thead>
<tr>
<th>Participant’s Name</th>
<th>Signature and Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigator / Delegate’s Name</td>
<td>Signature and Date</td>
</tr>
<tr>
<td>Witness’ Name</td>
<td>Signature and Date</td>
</tr>
</tbody>
</table>

The University of Calgary Conjoint Health Research Ethics Board has approved this research study. A signed copy of this consent form has been given to you to keep for your records and reference.
APPENDIX I - Consent Form for Randomized Controlled Trial Participation

TITLE:
The Impact of a Structured Exergaming Curriculum on Physical Literacy and Postural Balance in Older Adults

INVESTIGATORS

Dr. Larry Katz, Professor
University of Calgary - Faculty of Kinesiology -

Mr. Alexandre Monte Campelo, PhD student
University of Calgary - Faculty of Kinesiology -

SPONSORED BY THE SPORT TECHNOLOGY RESEARCH LABORATORY

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information. You will receive a copy of this form.

BACKGROUND

The senior population (65-years and over) is the fastest growing age group in Canada. Most
Canadians, including the elderly, do not meet the current recommendations for the amount of daily exercise. The lack of physical activity impacts both physical and mental health. In addition, a sedentary lifestyle can have far ranging consequences including: reduced physical functioning and increased number of illnesses, and a higher risk of falling. Exercise training is the most effective interventions in older adults for improving physical health and fall reduction. Exercise encourages overall mobility and increases confidence. Playing active video games has been shown to improve physical functioning and also the confidence to perform physical activity.

WHAT IS THE PURPOSE OF THE STUDY?

The overall goal of this research is to improve physical and mental functioning status of seniors and also to reduce the risks associated with aging such as the risk of falls. This research will explore the potential effectiveness of active video games compared to a regular exercise program.

WHAT WOULD I HAVE TO DO?

You will undergo a detailed assessment of physical and mental functioning three times: Before the study starts, at the end of the exercise program, and six weeks after the last session. During the assessments you will fill in questionnaires about your current physical activity status, your motivation and confidence when performing physical activity and you will perform physical tests such as sit down and stand up form a chair, walk few meters and balance yourself in one leg. The assessment will take approximately 30 minutes to be completed. You will be asked to attend 3 exercise sessions per week for 6 weeks for a total of 18 sessions. Each session will take place at a facility where you were registered. Each session of light to moderate physical exercises will take approximately 35-40 minutes. If needed a parking space will be provided or parking expenses will be reimbursed. You will be given a schedule with dates and timing for your sessions. You will be given a Fitbit Flex 2 wristband activity tracker which is a slim wristband worn similar to a watch on the non-dominant wrist for 24hr a day. This wristband will measure your physical activities based on arm movement. You will wear the wristband daily for 7-weeks, it includes a week of training on how to use the activity tracker and 6 weeks of exercising training. At the end of the study you might be asked to take part in a focus group. You will be randomly assigned to one of three groups using a random number generator: a traditional exercise program, an active video games program or a delayed active video games program. Participants included in the delayed active video game program will start the exercise program six weeks after the start of the study.

In an appropriate room, seven stations utilizing the active videogame equipment and accessories to promote physical activity will be available to the participants assigned to the active video game group. The video games include activities like stationary running, balance positions and eye-hand coordination. Those assigned to the traditional exercise group will perform exercises while standing up, sitting down on a chair or laying down on a mat. All the exercises for both groups will
be intended to improve muscular strength and endurance, and also to improve the balance and flexibility.

Prior to arriving for session, please:
- Eat a meal or a snack two hours prior to the session;
- If you take medications, please continue as advised by your physician and/or pharmacist;
- Wear a comfortable pair of shoes, a loose-fitting shorts/trouser and T-shirt.
- If for any reason you are not feeling well, have fever or any other health issue that can interfere in your daily activities please inform one of the investigators before starting the current session.

WHAT ARE THE RISKS?
As with any research procedures, there are some associated risks that you should be aware. There is possibility of feeling muscles soreness and tiredness after sessions. This muscle soreness is a temporary response to the progressively increased physical activity. Light to moderate physical exercises challenge the different body systems to work at a slightly elevated level than the regular baseline and is associated with a risk of exertion or fatigue sensation.

WILL I BENEFIT IF I TAKE PART?
This study may be beneficial, as the participants will have the opportunity to improve their physical abilities. Participants may also benefit from physical and cognitive performance analysis activities and the increased motivation and understanding towards a more active daily behavior.

DO I HAVE TO PARTICIPATE?
Involvement in this study will be completely voluntary, in which you are free to withdraw from participation in this study at any time without any consequence by simply writing a letter to researchers indicating as such.

WHAT ELSE DOES MY PARTICIPATION INVOLVE?
In this research, personal information that will be collected include name, gender, and physical literacy level however names will not be connected to the data for analysis and presentation of the results. We will videotape the experimental session so that it may be reviewed; the video will be used for research purposes only, given your consent.

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?
You will not be paid for participating and you will not need to pay for anything in this study.

WILL MY RECORDS BE KEPT PRIVATE?
Your information will be used to evaluate the effectiveness of the program by researchers. All participants will receive the collected information in the end of the program. The name of each participant will be locked in a separate secure cabinet from the information collected during testing. All field notes, journals or observations shall remain in the investigator’s possession or securely
locked in a filing cabinet inside the co-investigators office. Video files or photographic images will be kept for a very short period of time and used to verify testing results. At no time will any electronic information or image be shared with an outside source. Final disposition of data will occur in accordance with current guidelines established by the University of Calgary. The research team will make every effort to keep you informed of the progress in the study and if new information or changes to the study are required, you will be informed accordingly.

**IF I SUFFER A RESEARCH-RELATED INJURY. WILL I BE COMPENSATED?**
In the event that you suffer injury as a result of participating in this research, the University of Calgary, the Calgary Health Region and/or the Researchers will provide no compensation to you. Although, the researchers will make every effort to provide you a comfortable and safe environment while your participation. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

**SIGNATURES**
Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardizing your health care. If you have further questions concerning matters related to this research, please contact:

Dr. Larry Katz
Mr. Alexandre Monte Campelo

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary.

<table>
<thead>
<tr>
<th>Participant’s Name</th>
<th>Signature and Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigator / Delegate’s Name</td>
<td>Signature and Date</td>
</tr>
<tr>
<td>Witness’ Name</td>
<td>Signature and Date</td>
</tr>
</tbody>
</table>

The University of Calgary Conjoint Health Research Ethics Board has approved this research study. A signed copy of this consent form has been given to you to keep for your records and reference.
Exercises Played and Not Played during 11 October – 30 November 2018
Keep difficulty at “BEGINNER” level OR progress to “PROFESSIONAL” if desire to increase the intensity

WII FIT U WORKOUT (~30-40 minutes, includes instruction time)

ROUTINE:

WARM-UP (3 minutes)
• Use Free Step as a warm-up.
  o Participants free step (on and off) using a balance board. Allows a sense of control on activity intensity.
  o Requires: Wii Balance Board
  o Difficulty Level: Easy

• After 2 weeks, group can progress to Basic Step:
  o Step to the front, back, left, and right on the balance board to improve your sense of rhythm.
  o Requires: Wii Balance Board
  o Difficulty Level: Moderate
FLEXIBILITY GAME (5 minutes)
• Use Sun Salutation as a Flexibility exercise.
• Participants perform a yoga sun salutation which stretches back and tones arms and thighs.
• Requires: Balance Board
• Difficulty Level: Moderate

STATIC BALANCE (5 minutes)
Use Hula Hoop as a Static Balance exercise.
- Stand strong on the balance board. Sway your hips to spin the Hula Hoop. Helps pelvis alignment.
- Difficulty Level: Easy

After 2 weeks, group can progress into Super Hula Hoop:
- Advanced Hula Hoop with more calories burning.
- Difficulty Level: Moderate
STATIC BALANCE (5 minutes)
• Use Table Tilt as a Static Balance exercise.
  o Lean your body left, right, and forward, and backward to drop different colored ball in their respective colored holes.
  o Difficulty level: Difficult

STATIC BALANCE (5 minutes)
• Use Tilt City as a Static Balance / Coordination exercise.
  o Lean your body left, right, and forward, and backward to drop different colored ball in their respective colored holes.
  o Difficulty level: Difficult

DYNAMIC BALANCE (5 minutes)
• Use Ski Slalom as a Dynamic Balance exercise.
  o Participants lean left and right on the balance board to go through the gates. Also helps with coordination and strength as well.
  o Requires: Wii Balance Board
  o Difficulty level: Moderate
DYNAMIC BALANCE (5 minutes)
• Use **Trampoline Target** as a Dynamic Balance exercise.
  o Participants squat up and down and step on the balance board. Also helps with coordination and strength as well.
  o Requires: Wii Balance Board
  o Difficulty level: Moderate

DYNAMIC BALANCE (5 minutes)
• Use **Bird’s Eye Bull’s Eye** as a Dynamic Balance exercise.
  o Participants will flap their arms on the balance board. Also helps with coordination as well.
  o Requires: Wii Balance Board
  o Difficulty level: Moderate

STRENGTH (6 minutes)
Use **Rowing Squat** as a Strength exercise.
  o Builds your thigh and back muscles to help promote good posture.
  o Requires Wii Balance Board
  o Difficulty Level: moderate to difficult (intensity)
Use **Side Lunge** as a Strength exercise.
- Helps strengthen inner thighs
- Requires Wii Balance Board
- Difficulty Level: moderate to difficult (intensity)

**COORDINATION (5 minutes)**
- Use **Island Cycling** as a Coordination exercise.
  - Cycle through an island by maintaining constant pedaling through rhythmic left and right steps on the balance board. At the same time, use the Wii remote to steer through the island. Helps strengthen lower body.
  - Requires: Wii Balance Board, Wii remote
  - Difficulty level: Moderate to difficult

**COOL DOWN (2 minutes)**
- Use **Deep Breathing** as a Cool Down exercise.
  - Use a popular yoga deep breathing method to help improve metabolism.
  - Requires: Wii Balance Board
  - Difficulty level: Easy
APPENDIX L - Conventional Exercise Program

Objective: The curriculum is aimed to improve the physical fitness components of older adults by applying the exercise prescription guidelines and mixing different types of exercises.

Duration: The participants actively participated in 6 weeks training program. There were 3 sessions each week for a total of 18 sessions in six weeks. Each session lasts for 40 minutes approximately.

Types: Both programs followed the standard guidelines for fitness training programs and included warm-up, strengthening, flexibility, and balance and coordination exercises.

Progression: The exercises should progress in terms of repetitions and addition of exercises in each subcomponent on bi-weekly basis or participants pace.

Equipment: Gym mats, Weights (1lb., 2lbs., 3lbs), elastic bands, foam sticks and chair without arm rests.

Activities Summary:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm up exercises</td>
<td>5 Minutes</td>
<td>Warm Up</td>
</tr>
<tr>
<td>Strengthening Exercises</td>
<td>10 Minutes</td>
<td>Muscle Strength</td>
</tr>
<tr>
<td>Break</td>
<td>1 Minute</td>
<td>Rest</td>
</tr>
<tr>
<td>Balance Exercises</td>
<td>10 Minutes</td>
<td>Balance and Coordination</td>
</tr>
<tr>
<td>Stretching</td>
<td>10 Minutes</td>
<td>Flexibility</td>
</tr>
<tr>
<td>Breathing Exercises</td>
<td>5 Minutes</td>
<td>Cool Down</td>
</tr>
</tbody>
</table>

Total: 40 Minutes Approx.

General Precautions:
Advise these precautions in the start of each session;
- Never holding breath when performing exercises.
- Taking a snack half an hour before the activity, if diabetic.
- Stopping in case of any unusual pain, chest tightness, breathlessness fatigued and reporting to the instructor immediately.
- Following instructor guidelines, ask if there is any question.
(a) Warm Up

1. Static Stepping (20 steps), 1 Set

2. Trunk Rotations (Right and Left)
   12 repetitions, 2 Sets

3. Arm Circles Forward/Backward,
   12 repetitions, 1 Set

4. Wrist Circles
   Forward/Backward, 12 repetitions, 1 Set

5. Arm Scissors, 12 repetitions, 1 Set

6. High Knees Marching, 20 repetitions, 2 Sets
(b) Strengthening Exercises

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Type</th>
<th>Repetitions / Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gluteus Medius</td>
<td>![Image of exercise]</td>
<td>12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.</td>
</tr>
<tr>
<td>2 Quadriceps</td>
<td>![Image of exercise]</td>
<td>12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.</td>
</tr>
<tr>
<td>4 Gluteus Maximus</td>
<td>![Image of exercise]</td>
<td>12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.</td>
</tr>
<tr>
<td>5 Hamstrings</td>
<td>![Image of exercise]</td>
<td>12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.</td>
</tr>
</tbody>
</table>
(c) Balance and Coordination Exercises

Take 15 seconds break when moving from one exercise to other.

<table>
<thead>
<tr>
<th>#</th>
<th>Exercise</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bridging</td>
<td>10 reps (2 Sets). Maintain position for 10 seconds on the 10th rep.</td>
</tr>
<tr>
<td>2</td>
<td>Sit to Stand to Sit</td>
<td>12 reps (2 Sets)</td>
</tr>
<tr>
<td>3</td>
<td>Bird-dog</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Stepping in all directions (forward, side and backward)</td>
<td>3 Times. Step in all directions without losing balance.</td>
</tr>
</tbody>
</table>
(d) Flexibility Exercises

Stretch following muscles using 15 second hold. Assume the shown position and feel the gentle stretch. 2 Repetitions each side of body. Keep breathing during the stretching.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hamstrings</td>
</tr>
<tr>
<td>2</td>
<td>Gluteus Maximus</td>
</tr>
<tr>
<td>3</td>
<td>Gastrocnemius and Soleus</td>
</tr>
<tr>
<td>4</td>
<td>Lumbar Paraspinals</td>
</tr>
<tr>
<td>5</td>
<td>Shoulders</td>
</tr>
</tbody>
</table>

(e) Cool Down

1. Static Stepping (10 steps) 2 Sets

2. Controlled Breathing: 1 minute. Breathe in slowly and deeply through the nose. Keep the shoulders relaxed and upper chest quiet, allowing the abdomen to rise slightly. Relax and exhale slowly through the mouth.
APPENDIX M - Timed “Up and Go” Test

Directions
The timed “Up and Go” test measures, in seconds, the time taken by an individual to stand up from a standard arm chair (approximate seat height of 46 cm [18in], arm height 65 cm [25.6 in]), walk a distance of 3 meters (118 inches, approximately 10 feet), turn, walk back to the chair, and sit down. The subject wears their regular footwear and uses their customary walking aid (none, cane, walker). No physical assistance is given. They start with their back against the chair, their arms resting on the armrests, and their walking aid at hand. They are instructed that, on the word “go” they are to get up and walk at a comfortable and safe pace to a line on the floor 3 meters away, turn, return to the chair and sit down again. The subject walks through the test once before being timed in order to become familiar with the test. Either a stopwatch or a wristwatch with a second hand can be used to time the trial.

Instructions to the patient
“When I say ‘go’ I want you to stand up and walk to the line, turn and then walk back to the chair and sit down again. Walk at your normal pace.”

Variations
You may have the patient walk at a fast pace to see how quickly they can ambulate. Also you could have them turn to the left and to the right to test any differences.


Scoring
Time for ‘Up and Go’ test __________ sec.
Unstable on turning?
Walking aid used? Type of aid: __________
# APPENDIX N – Exercise Confidence Survey

## EXERCISE CONFIDENCE SURVEY

Below is a list of things people might do while trying to increase or continue regular exercise. We are interested in exercises like running, swimming, brisk walking, bicycle riding, or aerobics classes.

Whether you exercise or not, please rate how confident you are that you could really motivate yourself to do things like these consistently, _for at least six months._

Please circle one number for each question. How sure are you that you can do these things?

<table>
<thead>
<tr>
<th></th>
<th>I know I cannot</th>
<th>Maybe I can</th>
<th>I know I can</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>21. Get up early, even on weekends, to exercise.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22. Stick to your exercise program after a long, tiring day at work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>23. Exercise even though you are feeling depressed.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>24. Set aside time for a physical activity program; that is, walking, jogging, swimming, biking, or other continuous activities for at least 30 minutes, 3 times per week.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>25. Continue to exercise with others even though they seem too fast or too slow for you.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>26. Stick to your exercise program when undergoing a stressful life change (e.g., divorce, death in the family, moving).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>27. Attend a party only after exercising.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>28. Stick to your exercise program when your family is demanding more time from you.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29. Stick to your exercise program when you have household chores to attend to.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>30. Stick to your exercise program even when you have excessive demands at work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>31. Stick to your exercise program when social obligations are very time consuming.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>32. Read or study less in order to exercise more.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
APPENDIX O - Knowledge and Understanding of Physical Activity Questionnaire

Knowledge of Appropriate Frequency, Intensity, and Duration of Physical Activity to Achieve Health Benefits

Please answer the first 2 questions and circle your choice (TRUE or FALSE) on the last 5 questions:

1. What is the minimum number of days per week a person must be physically active in order to receive the ideal health benefit? ______________
2. What is the minimum length of time (in minutes) a person needs to be physically active throughout a typical day in order to achieve the ideal health benefit? ______________
3. A person must exercise vigorously to achieve the ideal health benefit. (TRUE) (FALSE)
4. Vigorous levels of physical activity are necessary to provide the ideal health benefit. (TRUE) (FALSE)
5. Moderate levels of physical activity do not provide any health benefits. (TRUE) (FALSE)
6. Ten minutes of physical activity three times per day provide the same health benefits as a single session of 30 minutes. (TRUE) (FALSE)
7. Everyone should get 30 minutes of moderate physical activity per day, most days of the week. (TRUE) (FALSE)
Motives For Physical Activity Measure - Revised (MPAM-R)

The following is a list of reasons why people engage in physical activities, sports, and exercise. Keeping in mind your primary physical activity/sport, respond to each question (using the scale given) on the basis of how true that response is for you.

<table>
<thead>
<tr>
<th>Not at all true for me</th>
<th>Very true for me</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

___ 1. Because I want to be physically fit.
___ 2. Because it's fun.
___ 3. Because I like engaging in activities which physically challenge me.
___ 4. Because I want to obtain new skills.
___ 5. Because I want to look or maintain weight so I look better.
___ 6. Because I want to be with my friends.
___ 7. Because I like to do this activity.
___ 8. Because I want to improve existing skills.
___ 9. Because I like the challenge.
___ 10. Because I want to define my muscles so I look better.
___ 11. Because it makes me happy.
___ 12. Because I want to keep up my current skill level.
___ 13. Because I want to have more energy.
___ 14. Because I like activities which are physically challenging.
<table>
<thead>
<tr>
<th></th>
<th>__ 15. Because I like to be with others who are interested in this activity.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>__ 16. Because I want to improve my cardiovascular fitness.</td>
</tr>
<tr>
<td></td>
<td>__ 17. Because I want to improve my appearance.</td>
</tr>
<tr>
<td></td>
<td>__ 18. Because I think it's interesting.</td>
</tr>
<tr>
<td></td>
<td>__ 19. Because I want to maintain my physical strength to live a healthy life.</td>
</tr>
<tr>
<td></td>
<td>__ 20. Because I want to be attractive to others.</td>
</tr>
<tr>
<td></td>
<td>__ 22. Because I enjoy this activity.</td>
</tr>
<tr>
<td></td>
<td>__ 23. Because I want to maintain my physical health and well-being.</td>
</tr>
<tr>
<td></td>
<td>__ 24. Because I want to improve my body shape.</td>
</tr>
<tr>
<td></td>
<td>__ 25. Because I want to get better at my activity.</td>
</tr>
<tr>
<td></td>
<td>__ 26. Because I find this activity stimulating.</td>
</tr>
<tr>
<td></td>
<td>__ 27. Because I will feel physically unattractive if I don't.</td>
</tr>
<tr>
<td></td>
<td>__ 28. Because my friends want me to.</td>
</tr>
<tr>
<td></td>
<td>__ 29. Because I like the excitement of participation.</td>
</tr>
<tr>
<td></td>
<td>__ 30. Because I enjoy spending time with others doing this activity.</td>
</tr>
</tbody>
</table>

What's Included?
You will be provided with one wristband, a removable Fitbit Flex 2 tracker, an USB plug, and a charging cable.

How do I take care of my Fitbit?
The Fitbit Flex 2 wristband is made of a flexible, durable material (similar to silicon) like many other sports and activity trackers. It is water-proof up to 100 meters below the surface. It is important to dry the band and device after any water based activities such as swimming, showering, or bathing for your own comfort and the protection of your skin and functionality of the device. **We do not recommend wearing Fitbit Flex 2 in a hot tub or sauna.**

How long does the battery last? How do I know when the battery is low?
Fitbit Flex 2’s battery lasts up to 5 days. If your battery is low, when you double tap your device, you'll see a flashing red light instead of green.

<table>
<thead>
<tr>
<th>Charged</th>
<th>Low Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="Image" alt="Charged" /></td>
<td><img src="Image" alt="Low Battery" /></td>
</tr>
</tbody>
</table>

Charging Instructions
1. Plug the charging cable into the USB port on your computer or USB wall charger.
2. Press the pebble into the compartment on the charging cable. The pins on the charging cable must align with the corresponding pins on the back of the pebble and lock securely in place. You’ll know the connection is secure when the pebble vibrates and you see the indicator lights blinking.
   a. We recommend plugging your charging cable into a USB port on your computer or other low-energy device. If necessary, you can use a UL-certified USB wall charger. Don’t use a USB hub or battery pack to charge, and only use the charging cable that the research team provided you.
3. While Flex 2 charges, each white light represents 25% of the maximum charge. When fully charged, you’ll see a green light and then all five lights will shine for a few seconds.

**We recommend recharging your “Fitbit Flex 2” every 5 days, preferably over night.**

Charging fully takes about two to three hours. We will download the data from your Fitbit every Monday.

**Weekly reminders will be sent to all the participants using their preferred method of communication.**

If you have any further questions on this subject, please do not hesitate to contact the following research team:

Mr. Alexandre Monte Campelo, PhD student -
APPENDIX R – Consent Form to Participate in Qualitative Study

TITLE:
The Impact of a Structured Exergaming Curriculum on Physical Literacy and Postural Balance in Older Adults

INVESTIGATORS

Dr. Larry Katz, Professor
University of Calgary - Faculty of Kinesiology -

Mr. Alexandre Monte Campelo, PhD student
University of Calgary - Faculty of Kinesiology -

SPONSORED BY THE SPORT TECHNOLOGY RESEARCH LABORATORY

You are being asked to consider participating in a focus group. This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully and to understand any accompanying information. You will receive a copy of this form.
WHAT IS THE PURPOSE OF THE STUDY?
You are being asked to participate in two focus groups. One to gather your expectations before starting the study and another to gather the feedback on your experiences with the exercises you have practiced during the study. The information obtained will be used to improve the experiences of future research and will assist the researchers in evaluating the effectiveness of the exercises programs.

WHAT WOULD I HAVE TO DO?
You will attend a session with other participants where you will be asked questions about your expectations and experiences in the exercise programs, and encouraged to discuss it amongst the group. To assure accuracy in capturing responses, the focus group will be audio recorded. These audio recordings will be transcribed for analysis. You will not be identified by your name. Unique identifiers will be used to separate data for transcription purposes and assure confidentiality. Instructors will not have access to the audio recordings or the unique identifiers that link the data to participants. Focus group data including audio recordings, and transcripts will be securely maintained accessible only to the research team and will be destroyed when these data are no longer needed. Involvement in this focus group will be completely voluntary, in which you are free to withdraw from participation in this study at any time without any consequence.

HOW MANY PEOPLE WILL TAKE PART IN THIS FOCUS GROUP?
The number of individuals participating in a focus group can vary but is usually kept to four or five participants to ensure that participants have an opportunity to express their opinions.

WHAT ARE THE RESPONSIBILITIES OF PARTICIPANTS?
If you choose to participate in this focus group, you will be asked to attend two meeting sessions with a group of participants of the three exercise groups: traditional exercise program, active video game program, and delayed active video game program. You will be asked to answer questions and engage in discussion about the exercises programs.

WHAT ARE THE RISKS OF PARTICIPATING IN THIS FOCUS GROUP?
Potential risks to you by participating in this focus group are minimal. People will be expressing their opinions about their experience and they may have conflicting opinions.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS FOCUS GROUP?
Bringing attention to your expectations and perspectives of the exercise program in which you might have participated has potential benefits as it will also inform improvement and/or the development of future research or supports available to seniors. Raising awareness about the challenges and strengths of seniors towards physical activity will also benefit the wider community and the state of knowledge related to exercising with active videogames

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?
You will not be paid for participating and you will not need to pay for anything in this study.
WILL MY RECORDS BE KEPT PRIVATE?

Your information will be used to evaluate the effectiveness of the program by researchers. The data of each participant will be locked in a separate secure cabinet from the information collected during testing. All field notes, journals or observations shall remain in the investigator’s possession or securely locked in a filing cabinet inside the co-investigators office. Audio recordings will be kept for a very short period of time and used to verify testing results. At no time will any electronic information be shared with an outside source. Final disposition of data will occur in accordance with current guidelines established by the University of Calgary.

The research team will make every effort to keep you informed of the progress in the study and if new information or changes to the study are required, you will be informed accordingly.

IF I SUFFER A RESEARCH-RELATED HARM, WILL I BE COMPENSATED?

In the event that you suffer any harm as a result of participating in this focus group, the University of Calgary, the Calgary Health Region and/or the Researchers will provide no compensation to you. Although, the researchers will make every effort to provide you a comfortable and safe environment while your participation. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

SIGNATURES

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the focus group and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardizing your health care. If you have further questions concerning matters related to this research, please contact:

Dr. Larry Katz or
Mr. Alexandre Monte Campelo

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary.

<table>
<thead>
<tr>
<th>Participant’s Name</th>
<th>Signature and Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigator / Delegate’s Name</td>
<td>Signature and Date</td>
</tr>
<tr>
<td>Witness’ Name</td>
<td>Signature and Date</td>
</tr>
</tbody>
</table>

The University of Calgary Conjoint Health Research Ethics Board has approved this research study.
A signed copy of this consent form has been given to you to keep for your records and reference.
APPENDIX S - Focus Group Pre-structured interview

FACILITATORS GUIDE

1. Refreshments and Introduction [5 minutes]
Welcome, and thank you for coming today. My name is ___________. We asked you come here today to share your opinions on the current exercise program that you just completed. Specifically, we would like you to share your opinions about which aspects of the program you liked and did not like.
This focus group will last about 1 hour. I will be taking notes during our discussion. Also, I’d like your permission to audio record the session to ensure that all of your comments are gathered and addressed correctly.
All of the information you provide during the discussion is confidential. This means that we will not use your name with your information. Are there any questions?

2. Focus-Group Questions

General questions:
Are you satisfied with your level of physical activity? If so, why? If not, why not?
Do you think that within the last six weeks you have become more confident about performing physical activity? Why?
Do you think that in the last six weeks you have become more competent (comfortable) while performing physical activity? Why?
Please describe your overall impression of the exercise program.
When you think back about your initial motivation for starting the exercise program, has it changed over time?
What motivated you to keep coming back and continue the exercise program?
How did the exercise program change your daily routine? Did you notice any changes as a result of participating in our exercise program? [psycho-social, physical, cognitive]
If available, would you like to continue this exercise program in the future?
What would you need in order to continue the exercise program?
What did you enjoy the most? Why?
What did you enjoy the least? Why?
Have you previously attended any exercise program? If yes, what were the primary differences in our exercise program compared to others?
Would you recommend our exercise program to your friends and/or family? Why?
Did your colleagues’ feedback change your initial opinion about the exercise program? Why?
Do you think that in the last six weeks your openness to new technology has changed?
Do you think technology can help keep you more active?
If you had to predict, over the next few months, do you think you will continue to regularly exercise? Would you use a fitness tracker? Would you use an active video game? Why? Please describe your overall impression of wearing the activity tracker wristband. Comment on any limitations or barriers you faced with your activity tracker wristband. Have you had previous experience using an activity tracker wristband? If yes, how was this experience different from the last one? How easy or difficult was it for you to remember to incorporate the wristband into your regular routine? Are there any recommendations on how we can improve the exercise program? Are there any other comments, related to the exercise programs or the use of technology to perform physical activity, that I didn’t ask you about tonight but are important for me to know?

Exergaming Group:
Which game did you enjoy the most? Why?
What were the most difficult activities? Why?
Have you had previous experience playing active video games? If yes, how was this experience different from the last one?
How different was your experience with active video games compared to regular exercise?

Conventional exercise Group:
How different was your experience compared to previous exercise programs?
Which exercise did you enjoy the most? Why?

We appreciate your time and participation in today’s session. The ideas and information you shared today are very valuable for this important research project.