2022-08-29

Understanding Engagement in Physical Activity Over the Life Course to Promote Healthy Aging

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Understanding Engagement in Physical Activity Over the Life Course to Promote Healthy Aging

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF DOCTOR OF PHILOSOPHY

GRADUATE PROGAM IN KINESIOLOGY

CALGARY, ALBERTA

AUGUST, 2022

Dissertation Abstract

The analyses presented in this dissertation reconceptualized the philosophical speculations that underpinned the epistemological foundations of Margaret Whitehead's Physical Literacy paradigm with attention to scientific claims of evidence. Establishing a scientific foundation for physical literacy as a holistic, immersive paradigm led to the notion that interactive experiences are laboratory exemplars for testing the motivation of Physical Literacy's holistic experiences. This led to a randomized, comparative trial (RCT) of two cycling interfaces - 2D monitor and 360° headset – that demonstrated, for both conditions, motivation to engage in physical activity while exergaming increased equally. Experiences associated with 2D monitors and 360° VR headsets with interactive cycling and gaming illustrated a safe and enjoyable way to engage seniors in mitigating sedentary behavior while actively engaging in physical activity. This has important implications for the design and development of exergaming systems. The results of the RCT study found that interactive exergaming while cycling with immersive interfaces led to increased enjoyment, was encouraging, and gave rise to an exploration that has potential to foster lifelong engagement in physical activity. A Delphi Method enabled experts to generate and discuss recommendations for healthier lifespans by managing physical and sedentary behaviors across the lifespan.

Keywords

Physical Literacy, Older Adults, Exergaming, Electronic Delphi Project

Preface

The following three chapters are based on articles that are published or submitted for publication in a peer-reviewed journal as of June 7, 2022.

Chapter 2 ***Manuscript Published***	Donaldson, G. D., Sheehan, D. P., & Katz, L. (2022). Physical Literacy Vindicated: The Mind Is the Function of a Body Embedded Brain. *Advances in Physical Education*, 12(02), 142-160. https://doi.org/10.4236/ape.2022.122011.
Chapter 3 ***Manuscript Submitted & Under Review***	Donaldson, G. D., Sheehan, D. P., Boyd, J., & Katz, L. (2022*). Older Adult Enjoyment, Perceived Effort, and Actual Effort While Riding Interactive Stationary Bikes in Different Virtual Levels of Chase-Based Exergaming Interfaces*. Faculty of Kinesiology. University of Calgary.
Chapter 4 ***Manuscript Submitted & Under Review***	Donaldson, G. D., Sheehan, D. P., & Katz, L. (2022). *Optimize Physical Activity & Mitigate Sedentary Behavior for Life: An Electronic Delphi Study - Retired Teachers Advise Adolescents*. Faculty of Kinesiology. University of Calgary.

The author of this dissertation was the main contributor to the conception, design, data acquisition, data analysis, interpretation, and writing of all chapters. The final manuscripts were edited with the help of the co-authors, and all articles were written under the supervision of Dr. Larry Katz.

Each research chapter is a self-contained manuscript. This is a Ph.D. “manuscript-based” dissertation that complies with the formatting guidelines (introductory chapter, research chapters, concluding chapter) set by the University of Calgary: (2018). *Thesis Formatting Guidelines*. Retrieved from https://grad.ucalgary.ca/sites/default/files/teams/3/thesis-guidelines.pdf.

Acknowledgments

My deep gratitude goes to my supervisor, Professor Larry Katz. Larry supervised my M.Sc. degree and then gifted me the privilege to join his Ph.D. program, where he patiently waited for me to reach this point. We both deserve gold stars for persistence. Thank you, Larry.

My appreciation extends to Dr. Jeff Boyd and Dr. Dwayne Sheehan for sitting on my Supervisory Committee, showing extraordinary flexibility as my dissertation took twists and turns that surprised even me. It was my privilege to have Dr. Boyd, Dr. Sheehan, and Dr. Katz as co-authors. This dissertation would not exist today were it not for their generous contributions.

Thank you to my co-supervisor, Dr. Penny Werthner. In a quiet, unassuming fashion, her presence spurred my progress into high gear when she came on board. Thank you, Dr. Werthner.

Many thanks to Professor Tak Fung for his patience and expertise as we honed the ANOVA statistics in preparing my Cycling manuscript for submission for publication.

My greatest appreciation goes to my high school and lifelong friend, my "guide on the side," Dr. Kenneth Ryba, for providing much-appreciated commentary, feedback, counsel, and direction at the most critical junctures of both my M.Sc. and Ph.D. adventures.

I am especially grateful to my ever resourceful and always caring spouse, Sheila Donaldson, for her lifetime of patience, tolerance, and support in one adventure after another. She has been my best friend and partner forever and was always there when needed. Thank you.

This dissertation exists because my communities were there for me when needed. Thank you, Eric Berndt, for creating and maintaining the Golden Bulldog association of retired teachers who once taught at Sir Winston Churchill. Thank you, Bulldogs Storme Blais, Sharon Carson-Bell, Neil Falkeid, Mike Fullerton, Kerry Porter, Heide Richells, and Greg Watson.

I sincerely appreciate the contributions of the above parties, but it was I who submitted the final draft of this dissertation for consideration. I alone am responsible for all errors and omissions.

Dedication

For my sons, the greatest gifts of my life,

Norman Donaldson and Gordon Donaldson

And for Their Mother, My Life Partner in All Ways

Sheila Donaldson, née Beaton

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List of Abbreviations

Abbreviation	Expression
2D	Two Dimensional
3D	Three Dimensional
360^{o} VR	Viewable in all directions
ANOVA	Analysis of Variance
AR	Augmented Reality
BNT	Basic Needs Theory
BPNT	Basic Psychological Needs Theory
HMD	Head-Mounted Display
MR	Mixed Reality
OIT	Organismic Integration Theory
PA	Physical Activity
PhD, Ph.D.	Doctor of Philosophy
PL	Physical Literacy
RCT	Randomized Comparative Study
RPE	Rated Perceived Exertion
SB	Sedentary Behavior
SDT	Self Determination Theory
VR	Virtual Reality
XR	Extended Reality

Epigraph

I was radicalized at age 15 by songs of social protest and William Ernest Henley's epic poem, Invictus. I was moved decades later when reading Nelson Mandela's autobiography while traveling East Africa in 2003 to learn that it was his favorite poem too. I recite it often.

Out of the night that covers me,
Black as the pit from pole to pole,
I thank whatever gods may be
For my unconquerable soul.

In the fell clutch of circumstance,
I have not winced nor cried aloud.
Under the bludgeonings of chance
My head is bloody, but unbowed.

Beyond this place of wrath and tears
Looms but the Horror of the shade,
And yet the menace of the years
Finds, and shall find, me unafraid.

It matters not how strait the gate,
How charged with punishments the scroll,
I am the master of my fate,
I am the captain of my soul.

Henley, W. E. (1888). Invictus. In *Book of Verses* (pp. 57-58). David Nutt.

Chapter One: Introduction

I took an academic nap in the 20th century and woke in the 21st century to learn, like Rip Van Winkle, I had slept through a litany of revolution in aging, brain science, mobile technologies, exercise equipment, streaming fitness workouts, virtual and augmented exergaming. I was excited before my nap, and now I am ecstatic to find myself in a candy store of emerging technologies and paradigms.

- Gerry Donaldson, Slumber Notes, 20 May 2022

1.1 Background and Significance

At the turn of the 20th century, life expectancy in Canada was 50 years. In 2009, life expectancy in Canada was an estimated 81 years (Conference Board of Canada, 2018). From 1980 to 2019, the average life expectancy in Canada rose from 75.4 to 82.1 (Statistics Canada, 2021). In 2020, over one billion people in the world were 60+ years old, a number projected to grow to 2.1 billion by 2050 (World Health Organization, 2021b).

The notion of healthy aging has shifted from the absence of disease to the functional ability of older people to do what they value (World Health Organization, 2021f), including mobility "for completing daily tasks and participating in activities" (World Health Organization, 2021b, p. 11). Engaging in physical activity (PA) while eschewing sedentary behavior (SB) is essential for healthful aging (Ramsey et al., 2021).

The World Health Organization (2020b) recommends that all adults spend 150-300 minutes of moderate-intensity aerobic PA weekly, or 75-150 minutes of vigorous-intensity aerobic activity, an equivalent combination, and two or more sessions of moderate muscle-strengthening activity. This dissertation aims to address a critical need for research on how older adults can be best motivated to engage in PA over their remaining lifespans by using recent, rapidly evolving exercise technologies and media.

1.2 Personal Motivation

1.2.1 A Ph.D. degree is about the love of wisdom.

The "Ph" in "Ph.D." stands for "philosophy" from the Greek *philo* (love) and *sophia* (wisdom), "the love of wisdom" (Mark, 2022). Wisdom goes beyond knowledge regurgitation, implying compassion and experiential self-knowledge (Grossmann, 2017). In my view, the most

important values of a Ph.D. study are innovation and compassion, contributions of new knowledge, and different ways of thinking about old knowledge in ways that benefit humankind.

Scientific experimentation is the gold standard for assessing evidentiary claims, but it is essential to tap other forms of knowledge and information through research such as stories, anecdotes, and documenting the shared wisdom of key informants. Scientific experimentation begins with hypotheses. Anecdotal evidence is generally and often deemed unreliable because rendition is subject to problematic biases and unfalsifiable claims. However, innovation requires novel hypotheses. Anecdotes, stories, and myths yield a rich reservoir of novel, untested hypotheses for the human sciences. We do well to remember the roots of hypotheses.

1.2.2 Physical Literacy is Holistic

The holistic paradigm of physical literacy (PL) offers a broad framework for thinking about PA and SB. Physical literacy is about movement "with competence and confidence in a wide variety of physical activities that benefit the healthy development of the whole person" (Mandigo et al., 2009, p. 6). Physical literacy describes the embodiment of the brain with the body. PL's foundational presuppositions are monism and embodiment (Whitehead, 2010d, 2019b).

This dissertation reflects my high regard for science and appreciation for human experience. In the twentieth century, the brain was scientifically opaque, but Margaret Whitehead generated a paradigm of "physical literacy" based on phenomenology and existentialism that posited that the mind was irrevocably physically and holistically intertwined with the human body and movement.

I hold Margaret Whitehead's paradigm of physical literacy in high regard. At the same time, however, it is important to incorporate new knowledge from advances in neuroscience. See chapter 2 (Donaldson, Sheehan, et al., 2022b).

1.2.3 Physical Activity Should Be Enjoyable.

I taught database management and a score of different computer programming languages in my decades-long high school teaching career and eight years managing the Department of Computer Science teacher outreach program at the University of Calgary. I spent the first two years of my Ph.D. retrieving and exploring dozens of virtual exergames, enjoying every title. I thus welcomed the opportunity to test my anecdotal hypothesis that exergaming while cycling a stationary bike was substantially more enjoyable than cycling without exergaming. See chapter 3 (Donaldson, Sheehan, Boyd, et al., 2022, submitted for publication).

1.2.4 Metaphor of Physical Activity: The Cowboy, the Horse, the Rope, the Quicksand.

I taught for forty years. My most effective teaching tactic was the saliency of metaphor.

This dissertation begins my journey to understand the interaction of two powerful human propensities that cooperate and compete, push, prod and pull the human body and brain toward health and illness, clarity and confusion of thought, function to do and dysfunction to thwart human agency.

Think of the old cowboy movies. Our hero's body is immersed in quicksand, clinging to a rope tied to the horn of his horse's saddle.

The quicksand of sedentary behavior sucks our hero toward illness and dysfunction while his horse of motivation pulls the rope of physical activity toward health and enough function to continue the good fight. The quicksand and rope are two different forces acting upon the health of our hero. Superficially, all we observe is the resulting behavior, but Anna Lembke (2021)

explains relevant processes in the brain, and Daniel Lieberman (2020) explains why these two different processes evolved in the human body. It is complicated, but so is the body and brain.

1.2.5 Older Adults Have Earned Wisdom to Share

I was privileged to teach computer science in the International Baccalaureate and Advanced Placement programs and author curricula for Alberta Education while working in a single high school with amazingly gifted and caring faculty who toiled relentlessly to deliver wholesome experiences for their students. Post-retirement, these faculty retained memories and lessons learned from a half-century of life experiences and associated reflections. The Delphi Method is an efficacious research process for gleaning "wisdom" from panels of "experts." Aging over a life course entails varying progressions of increasing dysfunction from inception to death. However, the same life course enables the accumulation of curated wisdom distilled from memories of experiences and lessons learned from those experiences. In February 2022, I convened a panel of nine retired high school teachers, myself included, from the high school where I taught adolescents for most of my career. The Delphi Method proved to be a practical approach for generating themes and grouping assertions by a panel of nine teachers asked to advise their 15-year-old selves on managing physical activities and mitigating damage from sedentary behaviors. See chapter 4 (Donaldson, Sheehan, et al., 2022a, submitted for publication).

1.2.6 Assumptions about the efficacy of technologies should be tested.

This dissertation documents that the *motivation* of enjoyment among older adults through interaction is similar when using 2D monitors and 360° VR headsets. Given the enormous costs of creativity, research and development, manufacturing, and distribution of fitness content, knowing that the *motivation* of enjoyment among older adults through screen interaction is

comparable for monitors and VR headsets can inform decisions around allocations of costly, finite resources that may enhance PA engagement. For example, a company may elect to develop media for tablets instead of or in addition to VR headsets.

1.3 Foundational Concepts

Foundational concepts are important principles and ideas that are combined to explain frameworks of more complex observations. This section identifies foundational concepts used to explain and understand theories and observations discussed extensively in this dissertation.

1.3.1 Physical Literacy

Physical Literacy is both a paradigm about the holistic nature of PA in human lives and a recommendation that directs individuals to take ownership of integrating PA into their lives for the duration of their lives. The PL paradigm is a holistic explanation of the prerequisites needed to promote human PA. "As appropriate to each individual, PL can be described as the *motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engaging in physical activities for life"* (Whitehead, 2019b, p. 8, emphasis in original).

One problematic ingredient of PL is motivation. What motivates people to engage in PA? Sedentary behavior, compulsive resting behavior, involves non-upright activities that expend no more energy than used to sit or lie down (Tremblay et al., 2017). What motivates people to resort to SB? If we begin to answer these questions, we can recommend practices that promote human engagement for PA and pragmatic management of SB in ways that increase the likelihood that people may enjoy a longer, happier, and healthier lifespan.

"Motivation to take part in physical activity is a fundamental attribute in being physically literate" (Whitehead, 2010b, p. 12). Whitehead (2010a) states, "Physically literate individuals

will exhibit a 'joy of movement,' and will celebrate, through movement, their ability to capitalize on their embodied capability" (p. 30). "Intrinsic motivation can be described as a drive to take action for the benefit of the experience itself and not as a means to other ends" (Whitehead, 2010a, p. 32).

Maintaining motivation to engage in PA over the lifespan can be challenging. It is important to maximize motivation to participate in physical activity, sustain application and engagement to apply oneself, and to take steps to include physical activity in one's life pattern (Whitehead, 2019a). Research across domains has shown that, compared to controlled motivation, autonomous motivation tends to yield greater performance, greater long-term persistence, and greater psychological health (Deci & Ryan, 2008). Sources of motivation can be both intrinsic and extrinsic (Whitehead, 2010b), but intrinsic (enjoyment) motivation is more persistent than external regulation. Taplin (2019), in recounting the personal histories of four adult PL journeys, found that participants who continued a lifelong appreciation and commitment to physical activity identified the physical activities as positive experiences. Laurie (2019), in discussing a strategy to promote PL, called for motivation to be a lifelong love of PA.

1.3.2 Exercise

Humans are averse to exercise, even though the human body requires copious PA to optimize a long, healthy lifespan (Lieberman, 2020a; Pontzer, 2019a). They generally avoid exercise, preferring to rest and conserve energy once needed for survival (Lieberman, 2020a; Raichlen & Alexander, 2017). The highest energy cost of animal brains is 10% of total energy used, yet the human brain's energy cost is 25% of total energy used (Harari, 2018a; Herculano-Houzel, 2016). Not surprisingly, humans prefer rest that conserves energy needed for survival (Lieberman, 2020a; Raichlen & Alexander, 2017).

Nevertheless, exercise is needed to maintain health. We know that endurance exercise reduces inflammation, the rate of reproductive cancers, stress, and insulin insensitivity, the immediate mechanism behind type 2 diabetes. Exercise improves the effectiveness of our immune system to stave off infection and produces enzymes that clear fat from circulating blood (Pontzer, 2019b, p. 29).

1.3.3 Sedentary Behavior

Sedentary behavior refers to "resting" activities such as sleeping, sitting, lying down, watching television, and other forms of screen-based entertainment (Pate et al., 2008). Objectively measured sedentary time has been reported to be high among older adults (Davis et al., 2011; Matthews et al., 2008). Sedentary lifestyles increase all causes of mortality, double the risk of cardiovascular diseases, diabetes, and obesity, and increase colon cancer risks, high blood pressure, osteoporosis, lipid disorders, depression, and anxiety (Prakash, 2002a).

A sedentary lifestyle is among the ten leading causes of death and disability in the world, with 60% to 85% of people in the world-leading sedentary lifestyles. According to the World Health Organization, sedentary lifestyles increase all causes of mortality. (Prakash, 2002b). Recent estimates from the World Health Organization (WHO) suggest that globally 23% of men and 32% of women, 18 years of age and older, are insufficiently active, with higher inactivity rates in Europe and the Americas. High-income countries had more than double the prevalence compared to low-income countries (World Health Organization, 2016).

Lee and Ellingson (2019) identified risks of sedentary behavior, or inactivity, across multiple domains. It impacts the socioeconomically disadvantaged. It is associated with obesity and chronic diseases. Psychologically it is associated with low knowledge and beliefs in

exercise benefits. Environmentally, we find it associated with reduced PE in schools. Leisure-time activities tend to be inactive gaming and no pet ownership.

We contrast this with evidence that the human body evolved to be active.

(1) Human bodies evolved to run hundreds of miles without stopping (Balke & Snow, 1965; Bramble & Lieberman, 2004; Essam, 2002).

(2) Human persistence hunting works by chasing prey to exhaustion, sometimes taking days.

Even when people realize the importance of exercise, it takes more brain resources to be physically active than sedentary. In an "approach-avoidance task" study at the University of British Columbia, using electroencephalography to measure cortical resources, researchers found that it took far more brain resources to move toward physically active images of avatars than toward sedentary images. (Cheval et al., 2018). Matthieu Boisgontier, who led the study with Boris Cheval, stated, "To me, these findings would seem to indicate that our brains are innately attracted to being sedentary" (Reynolds, 2018a). The results make sense from an evolutionary standpoint, Dr. Boisgontier said. "Conserving energy was necessary" for us as a species. Boisgontier explained that the fewer calories that atavistic humans burned, the fewer they had to replace when food was not readily available (Reynolds, 2018a).

Daniel Lieberman (2015) contends that humans evolved to avoid unnecessary exertion because energy from food was limited and that most anatomical and physiological systems evolved to require stimuli from physical activity to adjust capacity to demand. Significantly, past selection did not have to cope with the long-term effects of chronic inactivity.

Humans evolved to be unique among primates to being well-adapted for endurance instead of power (Lieberman, 2015, p. 314). "By any standards, exercise is clearly one of the most potent medicines there is (Lieberman, 2014, p. 16)." The human hunter-gatherer body has

only had ten thousand years to adapt to a sedentary lifestyle and insufficient time, as evidenced by widespread frequencies of "illnesses of civilization": cancer, obesity, type 2 diabetes, heart disease, and osteoporosis.

Humans require high levels of exercise to be healthy. For humans, unlike other living apes, "exercise is not optional; it is essential (Pontzer, 2019b, p. 28)."

1.3.4 Exergaming

Exergaming is a subset of computer gaming and involves technology-driven physical activities that require participants to be physically active (Witherspoon, 2013) using extended reality (XR) interfaces. XR is an "umbrella term" that describes digital technologies that extend perceptions of reality without creating the actual physical entities that they simulate (Qualcomm Technologies Inc., 2022). *Beat Saber*, the bestselling VR exergame to date, sold four million copies and 40 million in-app song purchases by 2021 (Smith, 2021). Exergaming has been shown to heighten the enjoyment of PA (Farrow et al., 2018; Farrow et al., 2019; Khundam et al., 2021; Qin, 2021; Ryan et al., 2006).

1.3.5 Aging as Pathology

Participants in both the Interactive Cycling Study (Chapter 3) and the Delphi Management Project (Chapter 4) were aged ≥ 65 years old. The World Health Organization (WHO) sponsors an ongoing campaign opposing ageism (World Health Organization, 2020a, 2020b, 2021a, 2021c, 2021d, 2021e). Ageism begins with conflating chronological and biological events.

> At the biological level, aging results from the impact of the accumulation of a wide variety of molecular and cellular damage over time. This leads to a gradual decrease in physical and mental capacity, a growing risk of disease, and ultimately, death. But these changes are neither linear nor

> consistent, and they are only loosely associated with a person's age in years. While some 70-year-olds enjoy extremely good health and functioning, other 70-year-olds are frail and require significant help from others (World Health Organization, 2018).

The WHO defines aging as a disease (Biogerontology Research Foundation, 2018; World Health Organization, 2020a). People do not age biologically at the same rate. "Whereas chronological aging refers only to the passage of time, biological aging relates to decline in function" (Hamczyk et al., 2020, p. 919). Smoking cigarettes can accelerate biological aging (Mamoshina et al., 2019) and calorie restriction and exercise can slow biological aging (de Cabo et al., 2014).

Nir Barzilai, founding director of the Institute for Aging Research at Albert Einstein College of Medicine, blames biological aging for most diseases, "Most chronic diseases are united by one primary cause – the biology of *aging itself* [Emphasis in original] (Barzilai & Robino, 2020, p. 14)." The Chief Science Officer of the Strategies for Engineered Negligible Senescence Research Foundation, Aubrey de Grey, believes that biomedical technology will eliminate age-derived debilitation and death. "Aging of the body, just like aging of a car or a house, is merely a maintenance problem" (de Grey, 2008, p. 21).

1.3.6 Older Adults

The number of older adults has significantly increased historically, especially in the past century. A typical person in the mid-18th century lived for about 29 years (Pinker, 2018). Life expectancy in Canada in 1950 was 68.29 years, increasing to 82.81 years by 2022 (Macrotrends, 2022).

Older adults place greater demands than young and middle-aged caregivers on health care systems (Volkwein-Caplan, 2013, p. 392), especially with increased age-related disorders such

as arthritis, heart disease, cancer, respiratory diseases, Alzheimer's disease, osteoporosis, diabetes, influenza and pneumonia, substance abuse, obesity, depression, oral illness, poverty and shingles (Vann et al., 2016). Improvements in sanitation, nutrition, medicine, and medical technology have increased the longevity of life and the quality of that longevity (Pinker, 2018, pp. 54, 58, 66, 72,73, 179, 182).

Sedentary behavior is deleterious to physical and mental health, while PA offers protection and benefits. Observational evidence indicates that greater time spent in sedentary activities is related to an increased risk of all-cause mortality in the elderly (Rezende et al., 2014). Some sedentary activities (e.g., playing board games, craft activities, reading, computer use) are associated with a lower risk of dementia, as is participation in physical activities (Verghese et al., 2003). Even light PA is significantly associated with the performance of executive functional assessments (Umegaki et al., 2018).

1.4 Self-Determination Theory

Self-Determination Theory (SDT) has experienced decades of theorizing and research into what motivates us to do what we do, a subset of which seeks to understand why we engage in physical activity and why we are sedentary.

While Skinnerian behaviorism was gaining traction, Edward Deci (1975) embraced "the conceptualization of intrinsic motivation which asserts that organisms have a general need for feelings of competence and self-determination" (p. 62). "It asserts that intrinsically motivated behavior is behavior which is motivated by one's need for feeling competent and self-determining (p. 62)." Ryan and Hawley (2016) posit that the association of proximal need satisfactions with moral and prosocial actions in individual development has yielded selective

advantages linked with the evolutionary roots of our human nature, that people typically experience benevolence as "need satisfying," and doing harm to others as "need frustrating."

1.4.1 The mind, including motivation, is a function and process of the brain.

The construct of "intrinsic motivation" rests upon the ontological premise that physical and cognitive wellness are holistically intertwined and that a hominid mind does not exist or function without a physical platform. "Minds are simply what brains do" (Minsky, 1986, p. 10). "I am who I am because my brain is what it is" (Churchland, 2013, p. 11). "Important within SDT is the idea that these active propensities for intrinsic motivation, internalization, and social integration are accompanied by, and indeed grounded in, specific phenomenal satisfactions. SDT posits that inherent in such pursuits are satisfactions in feeling competence, autonomy, and relatedness" (Ryan & Deci, 2017, p. 5).

1.4.2 Self-Determination Theory is a theory of Evolutionary Psychology

Existing humans are physically and psychologically adapted to previous environments. "The lag in time between the environment that fashioned our mechanisms (the hunter-gatherer past that formed much of our selective environment) and today's environment means that some of our existing evolved mechanisms may not be optimally designed for the current environment" (Buss, 2019a, p. 18). Modern humans are psychologically maladapted to modern environments because their psychological adaptations are those of hunter-gatherers.

> The human suite of psychological mechanisms evolved mainly during the period – 99% of human history – when people likely lived as hunter-gathers in small kin-based groups in African savannas and Asia and Europe. The seeds for present-day evolutionary mismatch were sewn roughly 10,000 years ago when agriculture arose and humans began living in contexts diverging from their hunter-gather past (Li et al., 2017, p. 38).

SDT references people's inherent growth tendencies and innate psychological needs as a basis for understanding the integration of personality, motivation, and behavior. (Ryan & Deci, 2000). "Although the theory is psychological, research has also given attention to biological underpinnings of these psychological processes and places them in an evolutionary perspective" (Ryan & Deci, 2017, p. 3).

The need for autonomy, competence, and relatedness have been found across cultures as different as America and South Korea (Sheldon et al., 2001). Basic Needs Theory (BNT) posits that all individuals have the propensity to satisfy three innate, universal psychological needs that people are motivated to satisfy (Gillison et al., 2019; Ryan & Deci, 2000).

(1) Autonomy - feeling that one is empowered and has a choice, a sense of volition, feeling that you are the causal agent of your decisions and behavior).
(2) Competence (feeling confident in being able to handle tasks), and
(3) Relatedness (feeling close and connected to people).

Satisfying these three innate psychological needs induces behavioral integration, proactivity, wellness, and optimal functioning (Ryan & Deci, 2002).

Deci and Ryan (2011) hypothesize that psychological need satisfaction predicts behavioral engagement because their satisfaction provides energy and direction to continue engaging in the behavior. Using BPNT, researchers have demonstrated that psychological need satisfaction links with well-being outcomes in physical activity contexts in a manner largely consistent with Deci and Ryan's (2004) contentions (Adie et al., 2012; Gunnell et al., 2011; Mack et al., 2012; Reinboth & Duda, 2006; Sylvester et al., 2012).

1.4.3 External Regulation Becomes Intrinsic When Personalized and Internalized.

Organismic Integration Theory (OIT) contends that the degree of autonomy determines the degree of extrinsic motivation. Extrinsic motivation depends on how much internalization and integration are associated with an activity. Internalization functions optimally when "people will identify with the importance of social regulations, assimilate them into their integrated sense of self, and thus fully accept them as their own" (Deci & Ryan, 2000). Integration "is the fullest, most complete form of internalization of extrinsic motivation, for it not only involves identifying with the importance of behaviors but also integrating those identifications with other aspects of the self" (Deci & Ryan, 2000, p. 236).

1.4.3.1 We Behave More for Joy than External Rewards and Punishments.

Edward Deci (2017) gave the following succinct introduction to Self-Determination Theory in a 2017 video presentation.

> Regardless of domain, such as workplace, schools, healthcare clinics, the way to produce optimal outcomes is to create the circumstances that support the basic psychological needs. Intrinsic motivation is to do something because you find it interesting and enjoyable. Extrinsic motivation is to do something because it leads to some separable consequence. People can internalize extrinsic motivation so they can own it as their own because they understand the value of the activity that may be rewarded or requested of them and come to identify with that value such that they integrate it as part of themselves.

1.4.4 Autonomous Motivation > Controlled Motivation > Amotivation

SDT predicts well-being and performance from types of motivation: autonomous and controlled motivation, and amotivation, the absence of motivation (Deci & Ryan, 2008, p. 182).

Autonomous motivation, inducing volition and self-endorsement, includes intrinsic and extrinsic motivation that people have integrated into their sense of self.

Controlled motivation, inducing pressure to think, feel, or behave in specific ways, includes both external motivations of reward or punishment and introjected regulation such as approval, avoidance of shame, contingent self-esteem, and ego-involvements.

Amotivation reflects a lack of intention and motivation, whereas autonomous and controlled motivation energizes and directs behavior. SDT traces motivation along a continuum from controlled to autonomous. Self-determination is least experienced when motivation is absent (amotivation) or without regulation. Self-determination increases with increased volition and internalization, peaking with intrinsic motivation.

Research across domains has shown that, compared to controlled motivation, autonomous motivation tends to yield greater performance, greater long-term persistence, and greater psychological health (Deci & Ryan, 2008). People tend to perform better when feeling self-directed than when feeling that they are regulated or oppressed.

Intrinsic motivation is the most autonomous form of motivation. It acts for the inherent enjoyment of the activity involved. When a behavior drives external forces such as guilt, shame, reward, or punishment, long-term health behavior change is unlikely (Ng et al., 2012).

A perceived locus of causality ranges from highly autonomous to highly controlling, allowing externally referenced contingencies to be internalized and integrated. They become more autonomous as they service internal rather than external goals.

1.4.5 Maximizing Persistence at Exercising Over Time

An important question that SDT can help address is how do we best induce urban dwelling, twenty-first century, human beings to engage in physical activity that is optimal for their well-being over their entire life course?

Variety support refers to how activities, behaviors, and opportunities are structured to facilitate (or thwart) the experience and refers to the extent to which a person feels as though they experience an assortment of tasks, actions, and opportunities (Sylvester et al., 2016). The authors found that receiving high exercise-related support led to greater perceived variety in exercise and an increase in exercise adherence behavior over six weeks. Sylvester, et al., (2018) also found that psychological need satisfaction moderated the relationship between perceived exercise variety and self-reported exercise behavior via autonomous motivation more when psychological need satisfaction scores were lower than average.

1.5 Other Motivation Theories

1.5.1 Flow Theory and the Autotelic Experience

Flow holds that motives are usually some combination of "autotelic" (intrinsically rewarding) and "exotelic" (extrinsically rewarding). Csikszentmihalyi (2015) defined flow as "a state in which you are so involved in an activity that nothing else seems to matter. The experience itself is so enjoyable that you do it for the sheer sake of doing it. Consciousness is harmoniously ordered. Your attention is singularly focused like a laser beam" (Csikszentmihalyi, 2015, p. 5).

Despite mystification of the flow experience in the popular press, Swann et al. (2018) reviewed the scientific progress of flow in sport and exercise. They concluded that research on the flow experience followed a "pattern of normal science" (p. 249). This is in contrast to a

paradigm shift where “at times of revolution, when the normal-scientific tradition changes, the scientist’s perception of the environment must be re-educated – in some familiar situations, he must learn to see a new gestalt” (Kuhn, 2012 orig 1964, p. 112).

“Flow refers to an optimal experience during which the mind and body work harmoniously while homed in on a specific task. …. When you are in a state of flow … you simply have the present moment; in that moment, the pleasure comes from the act itself” (Csikszentmihalyi et al., 2017, p. v). It is possible to cultivate an “autotelic” personality. “The key element of an optimal experience is that it is an end in itself. Even if initially undertaken for other reasons, the activity that consumes us becomes intrinsically rewarding” (Csikszentmihalyi, 1990, p. 67).

1.5.2 Intrinsic Motivation Varies with Perceived Competence

An individual’s “intrinsic motivation toward a particular activity will vary as a function of the degree to which they perceive themselves to be competent at that activity and believe themselves to be self-determined with respect to their performance of that activity” (Hein & Koka, 2007, p. 128). Competence motivation theory posits that positive, supportive behaviors from socializing agents foster intrinsic motivation (Harter, 1978, 1980). SDT views feedback as a social factor that impacts motivation and behavioral outcomes. “Externally administered rewards and contingencies can be coercive and controlling, but they can also signal competence or value and can be a form of positive feedback if wisely applied” (Ryan & Deci, 2018, p. 125). It is therefore crucial that feedback is perceived to be informational and not controlling.

1.6 The Research Problem

1.6.1 What is well established in the literature?

Both physically active and resting behaviors reflect different but complementary survival adaptations. This has been referred to as the paradox of physical activity (Cheval & Boisgontier, 2020). Preindustrial peoples were adapted to environments that few humans now occupy (White et al., 2009). Humans inherited an "endurance runner" body adapted for survival in wilderness environments, suited to a hunting and gathering lifestyle that demanded traveling long distances in search of food (Mattson, 2012; Raichlen & Alexander, 2020). Yet the desire to conserve energy by resting appears to be hard-wired (Speakman, 2020).

Motivation factors can be intrinsic or extrinsic (Ryan & Deci, 2017; Wasserman & Wasserman, 2021). Extrinsic motivations drive behaviors to obtain rewards such as money, grades, or status, whereas intrinsic motivations drive behaviors that are desired end states in and of themselves (Kruglanski et al., 2018).

Exergaming provides a context for explicit enjoyment. Exergame media now includes video (Chao et al., 2015), audio and tactile (Morelli et al., 2010; Morelli et al., 2011), augmented reality (Qin, 2021), virtual reality (Khundam et al., 2021; Stranick & Lopez, 2021)), and robotic exoskeleton (Bulea et al., 2017; Demoe et al., 2020; Graser et al., 2021).

1.6.2 Research Gap

A great deal has been written about older adults' healthy and active lifestyles (Cunningham et al., 2020; Lim et al., 2021; Loef & Walach, 2012; Tsai et al., 2020), but less is known about the background and life course experiences that contribute to maintaining PA and wellness in later life. Healthy aging is a lifelong learning journey, and attention needs to be given to factors that promote PA and PL throughout the life course.

There is a need to understand how new exercise technologies can be used to integrate practices of PA into the daily routines of older adults. Specifically, it is unclear whether and to what extent the use of VR may enhance enjoyment motivation.

A great deal of current literature and research has focussed on exergaming and VR exercise with younger people. Yet, little research has considered the role of exercise technologies and how these can be adapted to engage older adults in PA that is safe, accessible, and motivating. With this need in mind, the present research was undertaken to study exergaming methods and the extent to which these may enhance the enjoyment motivation of older adults under contrasting conditions. A second study utilized an e-Delphi survey technique with a panel of experts to explore the antecedents predisposing older adults to remain physically active in later years.

1.6.3 Why is this a problem?

Without motivation to practice, practice is absent! Existing research does not adequately inform the fitness industry about the usefulness of rapidly developing technologies such as interactive streaming over high-speed WiFi, interactive exergaming, and interactive streaming workouts that interface through two-dimensional screens such as tablets and monitors, and emerging virtual technologies such as VR, to help motivate older adults to take part in physical activity. For example, if it were known that participants experience comparable enjoyment from inexpensive monitors than more costly VR headsets, a company may target monitors instead of, or in addition to, VR systems.

1.7 Research Aim

Given the need to enable and motivate older adults to engage in PA and mitigate SB, this dissertation aims to identify and evaluate interactive technologies and living practices experienced by adults ≥ 65.

1.8 Research Objectives

RO 01. Compare scientific and philosophical justifications for the monism and holism a priori assumptions of Margaret Whitehead's PL paradigm.

RO 02. Examine the concept of PL to understand better how to enhance older adults' motivation to engage in PA.

RO 03. Compare the efficacy of different equipment and interfaces to promote the enjoyment of PA through exergaming.

RO 04. Identify strategies to manage PA and SB learned over a lifetime to optimize physical and cognitive health in the later years of life.

1.9 Research Questions

1.9.1 Research Questions - Physical Literacy Vindicated

RQ 01. What is the basis of existentialism and phenomenology for supporting monism over dualism claimed by Margaret Whitehead?

RQ 02. What is the basis of evolutionary science for supporting monism?

1.9.2 Research Questions - Interactive Cycling With & Without Exergaming

RQ 03. Is the enjoyment of PA in adults aged ≥ 65 greater when riding a stationary cycle with interactive exergaming than without interactive exergaming?

RQ 04. When participants ride a stationary cycle while interactive exergaming, do they enjoy a 360° VR headset or a 2D monitor interface more?

RQ 05. When participants ride a stationary cycle while interactive exergaming, do they perceive greater effort with a 360° VR headset interface or a 2D monitor interface?

RQ 06. When participants ride a stationary cycle while interactive exergaming, do they exert greater effort with a 360° VR headset interface or a 2D monitor interface?

1.9.3 Research Question – Managing Physical & Sedentary Behaviors for Life

RQ 07. What does a panel of retired high school teachers aged ≥ 65 collectively recommend to adolescents for attitudes and practices that best motivate them to engage in PA over the course of their lives?

1.10 Philosophical Foundations of Research

Philosophies determine the theoretical traditions and practice of research. For this reason, attention is given in this dissertation to understanding existing knowledge, the researcher's background and stance (ontology and epistemology), and the conscious engagement of the researcher himself in a critical reflexive process to develop new knowledge and direction for research (Auriacombe & Schurink, 2012).

1.10.1 Ontology

Ontology is a branch of philosophy that deals with the nature of reality and science of what is, and what can be said about the existence of human beings. An ontological approach develops categories to better understand the properties of the categories and the relationships between the categories. The construct of "physical literacy" rests upon the ontological premise that physical and cognitive wellness are holistically intertwined and that a mind does not exist or function without a physical platform. "A significant challenge in establishing the concept of PL is to help people understand the role of the lived embodiment and subsequently to show how this supports a monist view of human being." (Whitehead, 2010c, p. 23) "Minds are simply what

brains do." (Minsky, 1986, p. 10) "I am who I am because my brain is what it is." (Churchland, 2013, p. 11)

1.10.2 Epistemology

Epistemology deals with what is known and justifying how it is known. Questions of epistemology are paramount when contemplating the significance of virtual experiences because virtual technologies attempt to sufficiently change participants' perception into thinking and reacting to an artificial, fabricated, simulated presence as though it were an actual or "natural" presence.

For this research, quantitative and qualitative data were collected to document empirical observations and subjective information about meaning derived from lived experiences. This multidimensional analysis makes it possible to interpret and provide meaning about motivation to engage in various types and degrees of PA.

1.10.3 Methodology

There is a difference between methodology and methods. A methodology is a repeatable process of job-specific methods. A method is a tool for accomplishing a specific task. A methodology encompasses theories and conceptual frameworks that guide the selection of appropriate methods for a given study. Whereas research in the scientific tradition relies upon the scientific method, research in social sciences and humanities has relied on both quantitative and qualitative methods (Soltis, 1984).

This dissertation employs both quantitative and qualitative methodologies to understand and identify "relevant variables" that impact motivation to engage in PA (Table 1).

Table 1 *Research Methodologies of Studies that Constitute this Research*

Ch #	Dissertation Study	Research Methods	Description of Research
2	Physical Literacy Vindicated	Scientific Evidence *(Theoretical)*	The underpinnings for the monism and holism assumptions of Margaret Whitehead's physical literacy paradigm are explicated and compared with philosophical and scientific perspectives.
3	Enjoyment of Interactive Cycling While Exergaming	Randomized Comparative Trials *(Quantitative)*	A two-arm, parallel trial with random group assignment of participants aged ≥ 65 to one of two interactive interfaces compares enjoyment when cycling with and without exergaming and when exergaming while cycling with a monitor versus wearing a Virtual Reality helmet.
4	Managing Physical & Sedentary Behaviors For Life	Free Form Survey *(Qualitative)*	Round 1: Nine panelists aged ≥ 65 submitted prose replies to open-ended questions regarding reasons for engaging in sedentary and aerobic activities. The researcher converted prose replies to affirmative assertions.
	Electronic Delphi Mixed Methods	Fixed Response Surveys *(Quantitative)*	Rounds 2 & 3: Ordinal replies of nine panelists aged ≥ 65 to 115 assertions were recorded in frequency distribution tables. Cumulative percentage scores were calculated by summing the number of "Critically Important' and "Important" responses to the assertions.

1.11 Triangulation of Mixed Methods

This is a mixed-methods dissertation. Robert Yin recommends triangulation to validate qualitative work by "collecting evidence from different sources" (Yin, 2016, p. 79). The Randomized Control Trial (RCT) is generally deemed to be the "gold standard" for research investigation (Friedman et al., 2010; Portney & Watkins, 2009, p. 22). However, the very design of RCT assumes prior knowledge that enables plausible hypotheses and purposeful sampling. The field of kinesiology tends to be multidisciplinary, drawing upon disciplines from biological and psychological sciences and sports, recreation, and education (Kowalski et al., 2018). Using

both quantitative and qualitative methods capture rich data from a variety of sources, addressing questions not easily answered by one type of methodology.

Multiple types of inquiry and analysis methods through triangulation allow aspects of problems to be explored from different perspectives (Carter et al., 2014; Cohen et al., 2018a; Tracy, 2010). “Triangulation is a method used to increase the credibility and validity of research findings. Credibility refers to the trustworthiness and how believable a study is; validity is concerned with the extent to which a study accurately reflects or evaluates the concept of ideas being investigated” (Noble & Heale, 2019, p. 67).

Cohen et al. (2018b) and Denzin (2013) cite triangulation of methods as a source for ensuring internal validity in ethnographic research. This dissertation employs triangulation by design and not data generation. Triangulation at the design level usually uses quantitative methods combined with qualitative methods. The blending of approaches occurs at the level of interpretation and not during data generation or analysis (Nedjat, 2019). Convergent validity is demonstrated when finding that two factors that are assumed to be related to each other are related. Divergent validity requires two or more factors that ought to be unrelated and are shown in fact to be unrelated. Convergent and discriminant validity draw on triangulation of methods (Cohen et al., 2018b). A multi-method such as triangulation increases the authenticity of the meaning of a cultural phenomenon and is used when a more holistic view of outcomes is sought or where a complex phenomenon requires elucidation (Cohen et al., 2018b). “Credibility refers to the trustworthiness, verisimilitude, and plausibility of the research findings” (Tracy, 2010, p. 842). In the final analysis, credibility may be the most important virtue of triangulation.

1.12 Structural Outline

In Chapter One, the context of the dissertation and foundational concepts are introduced and the research objectives and questions are identified.

In Chapter Two (Donaldson, Sheehan, & Katz, 2022b), the evolution of the ability and need for persistent movement as a means of survival is documented. It argues that science has replaced existentialism and phenomenology in justifying and explicating the importance of PA and PL for human beings. It examines Margaret Whitehead's phenomenological and existentialist rationale for monism and "lived embodiment," finding that today's research supports both tenants. It argues that the mind is a function of the brain and not separate from a brain and that PA is holistically part of what it is to be human since the brain and movement coevolved in service of survival and reproduction of our species.

Chapter Three (Donaldson, Sheehan, Boyd, & Katz, 2022, submitted for publication), reports on a Randomized Comparative Trial with adults aged ≥ 65. Counter-intuitively, the findings indicated that exergaming inspired enjoyment with both a 2D monitor or 360° VR headset. The findings showed that enjoyment and perceived effort, but not actual effort, were significantly greater while riding a stationary cycle when engaged in exergaming than when not engaged in exergaming.

Chapter Four (Donaldson, Sheehan, & Katz, 2022a, submitted for publication) presents the results of an electronic Delphi survey in which a panel of nine retired high school teachers aged ≥ 65 provided advice to adolescents on optimizing PA and mitigating SB for life.

Chapter Five identifies contributions to knowledge generated by this dissertation, describes the linkages between the three manuscript projects, and provides a concluding summary of the key findings, contributions, and recommendations for future research.

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Chapter Two: Physical Literacy Vindicated

"Physical fitness is not only one of the most important keys to a healthy body;

It is the basis of dynamic and creative intellectual activity."

- John F. Kennedy (1960)

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This chapter is a reproduction of Donaldson, G. D., Sheehan, D. P., & Katz, L. (2022). Physical Literacy Vindicated: The Mind Is the Function of a Body Embedded Brain. *Advances in Physical Education*, 12, 142-160. https://doi.org/10.4236/ape.2022.122011] Creative Commons Attribution International License (CC BY 4.0). http://creativecommons.org/licenses/by/4.0/

Abstract

Margaret Whitehead purports that a belief in monism and holistic perspective results in a “lived embodiment” that is fundamental to the appreciation of physical literacy. In this article, we document how our species evolved the ability and need for persistent movement as a means for survival and discuss the merits of Whitehead’s perspective from both a philosophical and scientific perspective in the context of physical literacy. We argue that science has replaced existentialism and phenomenology in justifying and explicating the importance of physical activity and physical literacy for human beings.

Keywords

Physical Literacy, Monism, Embodiment, Phenomenology, Existentialism

2.1 Introduction

Prior to the twentieth century, the prevalent view was that the mind was non-physical, fixed, and pre-existing, a cartoon version of reality (Graziano, 2021). Empirical neuroscience research in the twentieth-first century demonstrated instead that the mind is an embodied process of a brain within a body, interacting with its environment (Johnson & Tucker, 2021). Embodied cognition has three themes (Shapiro, 2019).

(1) The properties of an organism's body limit or constrain the concepts that it can acquire.

(2) The digital computer model of cognition is replaced by empirically analog models.

(3) The body and world interact constitutively rather than one causing the other.

In this article, we examine the notion of Cartesian dualism that differentiated the brain and mind as separate entities based on the current scientific knowledge about the brain and human evolution. We describe four perspectives on the nature of what it is to be human: 1) the philosophy of monism, 2) the science of monism, 3) the philosophy of lived embodiment, and 4) the science of lived embodiment.

Early 20th-century science faced an identity crisis. Science was just getting accustomed to James Maxwell's linkages of electricity, magnetism, and light as different variations of the same phenomenon when along came Albert Einstein with his 1905 Special and 1915 General theories of relativity spouting unintuitive explanations of the relationships between space, time, mass, and energy. Accompanying these shocks to conventional existential views of nature were the historically devastating ravages of hate-mongering tribalism expressed as two grotesque world wars and the weaponization of science culminating in threats of genocide and nuclear holocaust. Important ontological questions were asked. What is real? What is it to be human?

One response was Karl Popper's crystallization of the scientific method (Popper, 2002, Original German Published in 1935), followed by Thomas Kuhn's reconceptualization of science as paradigms of changes in world views (Hacking, 2012; Korzeniewski, 2019; Kuhn, 2012 orig 1964). A second response was by Edmund Husserl, followed by Martin Heidegger's foundational work on the method of phenomenology (Bragg, 2015; West, 2017).

The core logic of the scientific method is the testing of ideas with evidence (University of California Museum of Paleontology, 2019). On the other hand, phenomenology distinguishes between comprehending subjects (humans) and comprehended objects (real world). The scientific method builds models of reality based on objects that would exist independent of human consciousness. Phenomenology builds models based on "phenomena" created after input from our senses is filtered by assumptions and biases.

In this persuasive essay, we examine how modern science has replaced philosophy. Specifically, we argue that scientific support for PL has superseded reliance on philosophical underpinnings. Historically, Whitehead's explication of PL referenced phenomenology and epistemology instead of science, so that perspective is also addressed.

2.2 Monism

Educators long placed cognitive skills in high esteem. Educational policy was premised on the false dualist assumption that the mind and body were separate entities, giving short shrift of time and status to physical education. PL is a countervailing paradigm that posits that the mind is holistically a part of the body and cannot exist without a body. Modern science has empirically demonstrated that increased cognitive performance is linked to and undergirded by increasing physical capacities, predicted by the PL paradigm.

2.2.1 Low Status of Physical Activity Was Linked to Dualism

When Margaret Whitehead was a professor at the University of Bedfordshire, she had a "deep-seated belief in the *significance and value of physical activity* for all" [emphasis in original] (Whitehead, 2018, p. 1). However, Whitehead was troubled that PA held "low status in the UK, in education, and thus in the curriculum" (Whitehead, 2018). She felt that PA should have respect commensurate to any academic courses " (Whitehead, 2018). She disagreed with the dualistic perspective used in the UK educational system, treating the body and mind as separate entities, and viewing the body as simply a vessel that houses thought" (Whitehead, 2018).

Physical literacy posits that human physicality and movement be considered part and parcel of all things human (Whitehead, 2018). The term PL was first introduced into the physical education literature in 1938 (Robinson et al., 2018). A salient feature of Whitehead's belief has been her persistent insistence that PL is conceived monistically (Whitehead, 2010e, 2019b, 2019c).

Whitehead's definition of PL is rooted in the concept of grounding philosophy within human experiences. Research and practice that reference her definition empirically are often simplistic attempts to implement or link that philosophy for institutional gain, ironically sometimes decentering the holistic nature of her definition (Jurbala, 2015). Indeed, the theoretical fluidity of Whitehead's definition of PL has led to the emergence of various conceptions of the term beyond phenomenology, including in motor development, practical applications, and the political sphere (Jurbala, 2015).

Nonetheless, monism and embodiment are foundational Whitehead presuppositions of PL (Whitehead, 2010d, 2019b). They are necessary and perhaps sufficient preconditions to viewing

a human being, not as a sequence of singlet states from birth to death, but as a dynamic, integral part of a larger, more dynamic process. This idea is captured in recent literature that conceptualizes PL as dynamically communicative between the embodied self and the environment (Jurbala, 2015) or as an integrated and overlapping individual-environment system (O'Sullivan et al., 2020).

2.2.2 Cartesian Dualism Is the Culprit of Educational Curricula

Cartesian dualism, named after the 17th-century philosopher René Descartes, postulated that the human mind is a thing separate from the human body; that the mind existed separately from the body and may persist even beyond the death of a human body (Descartes, 2018, orig 1637). The notion that the mind can be disembodied from a physical body may be apparent in physical education curricula, which separates physical and academic courses and classes, effectually treating the mind and body as different entities.

Thought does not exist independently of a brain or facsimile. Thought is what a brain does. It makes as much sense to speak of thought without a brain as eating without a mouth or walking without legs. The mouth eats. Legs walk. The brain thinks. When the body dies, the mouth stops eating, the legs stop walking, and the brain stops thinking.

The notion that thought happens independently without a material platform such as a brain is called dualism. The notion that thought is a function of a material platform like a brain is called monism. "In the philosophy of mind, dualism is the theory that the mental and the physical—or mind and body or mind and brain—are, in some sense, radically different kinds of thing" (Robinson, 2020).

2.2.3 Monism Is an Empirically Observational Proposition

Monism holds that humans are defined by affective, physical, and cognitive domains and that these are intricately interrelated (Whitehead, 2019b). Monism is important if people are to treat humans holistically. The holistic nature of being human means that experiences impact the affective, the physical, and the cognitive (Taplin, 2019). The central premise of monism is that the body and the mind are one intricately intra-dependent whole (Durden-Myers & Whitehead, 2019a).

2.3 Embodiment

2.3.1 Physical Activity as Embodiment—A Paradigm Shift

The introduction of PL initially presented a paradigm shift in the way educators thought about the role of PA in school curricula and then more broadly, for all people everywhere (Whitehead, 2010a). Physical education is any purposeful PA within the curriculum in compulsory schooling (Whitehead, 2010e). Whitehead's philosophy of PL advanced a different way of thinking about the role that PA played in the lives of people as embodiment, "the potential individuals have to interact with the environment via movement. This covers both the embodiment-as-lived as well as the embodiment as an instrument or object" (Pot et al., 2018; Whitehead, 2010e, pp. 202-203). This represented a shift in vision, a revolution in a world view that applied beyond the physical education curricula and courses in UK schools. The notion that PA is experienced as "embodiment" was a revolutionary gestalt that required a complete rethinking about how to incorporate PA in school curricula and the full life course of all persons. "Therefore, at times of revolution, when the normal-scientific tradition changes, the scientist's perception of his environment must be re-educated – in some familiar situations, he must learn to see a new gestalt" (Kuhn, 2012 orig 1964, p. 112).

2.3.2 The Mind Is an Executing Brain

There may be no such thing as "normal science" (Kuhn, 2012 orig 1964). However, there is a consensus that scientific ideas need to be replicable, that there need to be multiple lines of evidence drawn from different sorts of tests and different fields of study, and that evidence needs to be publicly available for scrutiny (University of California Museum of Paleontology, 2019).

Science requires that assertions be evidence-based and publicly available for scrutiny. Monism is a scientific fact. The brain is a noun. The mind is a verb. "Minds are simply what brains do" (Minsky, 1986, p. 10). People's phenotype (P) is the product of the interaction of their genotype (G) with experience and environment (E): $P = f(G, E)$. This formula is axiomatic to understanding biology.

The construct of PL rests upon the ontological monistic premise that physical, cognitive, and emotional wellness are holistically intertwined (Whtehead, 2010). A hominid mind does not exist or function without a physical platform. A significant obstacle to internalizing PL is showing how lived embodiment supports a monist view of a human being (Whitehead, 2010c). "I am who I am because my brain is what it is" (Churchland, 2013, p. 11).

Steven Pinker (2003) told his TED Talk audience that genetics and neuroscience are increasingly showing that the brain is intricately structured (2:43) and that brain differences are just differences in anatomy, … with consequences in thought and behavior…. (4:05). By 2018, Whitehead et al. (2018, p. 254) confidently claimed that practically all neuroscientists refuted dualism.

Humans inherit brains that enable minds. In rejecting notions of dualism, Steven Pinker (2002) followed the 21st-century confluence of evidence from cognitive science, neuroscience, and ethnology. "[T]here can be no learning without innate circuitry to do the learning" (Pinker,

2002, p. 35). “One can say that the information-processing activity of the brain *causes* the mind, or one can say that it *is* the mind, but in either case, the evidence is overwhelming that every aspect of our mental lives depends entirely on physiological events in the tissues of the brain” [emphasis in original] (Pinker, 2002, p. 41).

2.4 Phenomenological Perspectives

2.4.1 Humans Are of the World and Not Just in the World

In a 1924 lecture, *The Concept of Time,* Heidegger (1992, orig 1924) proposed a reconceptualization of what it is to be human. “Our inquiry points in the direction of Dasein or ‘being there’ Heidegger (1992, orig 1924, p. 6E). Heidegger (1992, orig 1924) argued that Dasein (human) could not be reduced to a biological body or zoological species, nor to minds or consciousness. He was searching for what people really mean by “being.” Heidegger talked about “being *in* the world” as being involved with other beings [emphasis in original] Heidegger (1992, orig 1924, p. 7E).

Durden-Myers and Whitehead (Durden-Myers & Whitehead, 2019b) see the influence of existentialism in the notion that people become human by interacting with the world. Humans do not literally create anything, for humans are as constrained by the laws of physics as is the rest of the cosmos. However, the body is of the environment and not just part of the environment. The tail of a dog is of the dog. When the dog is excited, the tail wags because the tail is of the dog.

Analogously, a human is the constituent part of its environment and not a being set apart from it, and not simply a sum of the parts. The larger environment is the coffee, and humans are the creams. The human body is not a single “thing.” Microbial cells in human bodies outnumber human cells by perhaps ten to one. Ninety-nine percent of the genes in the human body come

from microbes (Knight & Buhler, 2015). The microbes are of the human body and not simply inside the human body. The human body is partially the microbes, and the human experience is an environmental process of the interaction between the microbes and the rest of the body. A 21st-century science-based paradigm of the human body does not so much contain microbes as being, in part, defined by the microbes and the internal environment within the body that houses the microbes. This is a scientific, evidenced-based, testable paradigm that supports Whitehead's introspective, existentialist holistic conception that human nature cannot be separated from human embodiment (Durden-Myers & Whitehead, 2019b; Pot et al., 2018). People cannot use the scientific paradigm to determine whether Whitehead's phenomenological deductions are correct but using science does allow them to arrive at similar conclusions, albeit for different reasons.

2.4.2 The Problem with Grounding Physical Literacy in Phenomenology & Existentialism

A major challenge to phenomenology and existentialism is that they are mental constructs and not "objects" of the world. The objects of these philosophies are mental phenomena in the abstraction that is the mind. Husserl argued that human experience is not objective; that experience is based upon sensing the real world through a default state of uncritically accepted beliefs that he called "the natural attitude" (Manen, 2014, p. 43). He may be correct, but people cannot know this because people cannot enter his mind, play with its contents, and experiment within his mind.

The surmises of phenomenologists might well be correct, but their hypotheses are only testable by logic and not by experimentation. The objects of phenomenology and existentialism cannot be weighed, measured, or physically observed. Like shadows on the wall, they reflect a distillation of reality but not reality itself. Their hypotheses are not falsifiable. Someone must

enter your mind to observe what you observe, but they cannot enter your mind, and therefore, they cannot know what you know except by what you describe. This then results in hearsay knowledge, a type of knowledge that is not empirically credible because hearsay knowledge relies upon the beholder's perception. Therein lies the irony. In phenomenology, “phenomena” perceived by the mind do not depict reality but rather depict filtered versions of reality distorted by assumptions and beliefs.

The irony is that because phenomena of the mind cannot be relied upon, neither can people rely upon its methodology; the resultant is a private phenomenon and not a public outcome.

2.5 Embodiment: Human Brain is an Organ, not a Computer Component

2.5.1 Embodiment via Existentialism and Phenomenology

Bodily experiences physically impact brain performance and functionality. Brain functionality, or “mind” or “thoughts and emotion,” is an “embodiment” phenomenon.

Whitehead (2007) set forth her adaptation of the philosophical basis for the meaning and significance of “embodiment in life” (p. 282) in the philosophy of PL, referencing, among others, existentialist Jean-Paul Sartre (1956) and phenomenologists Maurice Merleau-Ponty (1962) and Ian Burkitt (1999) in rejection of Cartesian dualism and explication of the role of “embodiment in life” in service of the realization of people’s full potential.

Embodiment philosophically states that humans are at one with the world that they can only experience with their bodies and presumably not with a separate mind. Existence is realized and experienced by bodies through their reciprocal interaction with the world. Humans are with the world rather than objects in the world. It is people’s movement in the world—Whitehead uses the term “motility”—that facilitates their social as well as physical experience with the

world (Whitehead, 2001). Existentially, humans create themselves through their interaction with the world.

Phenomenologists tend to disagree about the content of phenomenology:

> What unifies the tradition of phenomenology is…a shared preoccupation and a shared conception of method and…the fact that we grasp and comprehend all of the various entities, objects, activities, and events that the world throws at us in the course of our everyday experience…and…they're intelligible to us so what they're interested in the way that reality manifests itself to ordinary human subjects…that relationship between appearance and reality (Stephen Mulhall speaking at 1 min 24 secs in Bragg, 2015).

Whitehead (2007) surmises that humans are embodied rather than having a body and that embodiment contributes to human life through self-realization, perception, concept development, language formulation, rationality, emotion, and the development of interpersonal relationships. Humans are "beings-in-the-world," and their "body is integral in, and indispensable to, realizing our [their] very existence" (p. 282).

Whitehead (2007) infers from Burkitt (1999) that meaning comes not from rules of cognition or grammatical construction but from people's "embodied interaction with the world" (p. 284). For Whitehead (2007), "there is no doubt that our motile capacities are absolutely crucial to the contribution made to existence by our embodied nature" (p. 283). Embodiment makes intellect possible.

2.5.2 The Human Brain Is Not a von Neumann Computer

von Neumann computer architecture, named after work in the 1940s by mathematician and physicist John von Neumann and others, follows the stereotypical Input-Process-Output

model of computer processing (Centre for Computing History, 2021). A central processing unit contains a control unit and an arithmetic/logic unit that receives digital input, exchanges data with a memory unit, and generates output data. That is not how the human brain retrieves and processes information. Rather, the human brain is the organ that enables the mental processes of the human mind. Real-life sensual perceptions get processed while memories are constructed.

The human brain is a complex organ that carries a legacy of adaptations to prehistoric environments and uses cognitive biases, heuristics, and rules of thumb in making judgments and decisions (Kahneman, 2011). Unlike a von Neumann computer that processes raw data as collected, the human brain constructs mental models through interaction with perceptions that are sensory impressions shaped by cognitive biases. The human brain constructs memories through synaptic modifications that do not precisely mirror reality. This statement is a derivative of both science and phenomenology.

The human brain was engineered by natural selection to maximize the number of progenitors and not by software to implement algorithms electronically. Hodent (2018) describes the evolution of the human brain:

> The human brain began evolving well before any hominids walked the Earth and has further evolved over thousands of generations as our ancestors survived the harsh life of the African savanna. However, our modern life is very different from prehistoric times, and we face many problems that are new for our brain in terms of the relatively slow scale of evolution (Hodent, 2018c, p. 9).

2.5.3 Human Minds Are Electro-Chemical Patterns in the Wetware of a Brain

Computers and human brains have different substrates. The human brain is not a computer processor, but both processor and brain are platforms that retain and process physical

representations of abstractions. Computer data is algorithmically manipulated as electrical patterns in a computer hardware processor. Computers have a digital architecture, whereas human brains have an analog morphology. Both platforms have in common that both store and manipulate abstract representations of real-world information. Information, such as thoughts, is manipulated as electro-chemical patterns in the wetware of macaque, human and other brains.

2.5.4 Perception

The science of perception resonates with Heidegger's (1924/1992) description of reality as objects and events as they are perceived or understood in human consciousness, except that cognitive science does not include untestable abstractions.

Perception is the brain processing sensory information to make sense of it; humans don't perceive the world as it really is but instead perceive representations of it (Hodent, 2018d). Perceptions are processed as cognitively massaged data and not exclusively as raw data. The brain and its mindful functions were not engineered for digital accuracy (Barrett, 2020; Cobb, 2020) but instead for successful or benign adaptations to past environments that promoted procreation over extermination. Memory is not just a record of events. Memory can change, and memory can be false (Barrett, 2020; Cobb, 2020) and serve successful or benign adaptations to past environments that promoted procreation over extermination. Memory is not just a record of events. When an imperfect sensory impulse signaled that there was a slight possibility that a venomous snake lurked in the shadows, the ape that took time to rationally reflect on whether the shadowy perception was reality or illusion stood a higher likelihood of being permanently removed from the ape gene pool than did the ape that impulsively took flight. The impulsive ape is the humans' ancestor, the one with the brain engineered for survival over contemplation, the ape that shoots first and asks questions later. The *Homo sapiens* brain is malleable (Eagleman,

2020; Marcus, 2004; Merzenich, 2013). The emergence of virtual environments, gaming, and applications in the 21st century have amply demonstrated that the Homo sapiens ape brain can be willingly manipulated by virtual environments that defy empirical laws of physics (Hodent, 2018a). "VR [Virtual Reality] changes the world we're in, and we accept the illusion eagerly" (Fink, 2018, p. 30). It is a brain adapted for survival as well as a rational calculation that allows for broad variation in senses of presence.

2.5.5 Memory

Brain areas are functional components and not necessarily physical regions. The architectural model of human memory has three components: sensory stores, short-term stores, and long-term stores (R.C.Atkinson & R.M.Shiffrin, 1968). Sensory memory is part of perception; short-term memory stores items for less than a minute (Peterson & Peterson, 1959). Working memory is a type of short-term memory that allows people to store and process information temporarily. It is working memory that accomplishes executive functions and complex tasks. The human brain has limited attentional resources and is poor at multitasking. Long-term memory is not limited by time or space (Hodent, 2018b, pp. 35-44).

Memory is a reconstruction process and not one of storage and retrieval of data (Hodent, 2018b). Each time humans reconstruct a memory, they retrieve, not sensory data, but rather a processed or massaged past memory, which again undergoes further processing (Hodent, 2018, Chapter 4). Memory is a process of adaptation for survival and an engineered store of information.

2.5.6 Attention

Attention is the selective focusing of consciousness and receptivity (Merriam-Webster Dictionary, 2019). Attention decreases when humans attempt multitasking. When multitasking,

humans actually “switch” among tasks and may experience “interference” in decision-making, effects described as a “cognitive bottleneck” (Borst et al., 2010; Welford, 1967). Even brief mental blocks created by shifting between tasks can cost as much as 40 percent of someone’s productive time (Rubinstein et al., 2001). Learning suffers if attentional resources exceed working memory limits (Sweller, 1994). The brain switches between tasks so fast that we think that we multitask, but the brain actually performs tasks sequentially (Gupta, 2021). The costs of switching during multitasking can challenge attention and thus reflexes.

2.5.7 Embodiment

Whitehead argues that PL is an embodiment phenomenon and that it is holistic (Whitehead, 2010d, 2019b). Holistic embodiment makes sense when people track the correspondence between fundamental movements and cognitive skills, although fundamental movement skills are not synonymous with an embodiment.

To some great extent, PL is about movement “with competence and confidence in a wide variety of physical activities that benefit the healthy development of the whole person” (Mandigo et al., 2009, p. 6).

We have reviewed scientific evidence that refutes Cartesian mind-body dualism without reliance on existentialism and phenomenology. Scientific evidence demonstrates that the “mind” is not a “thing” but a set of brain functions. The philosophies of existentialism and phenomenology are unnecessary to refute Cartesian dualism and accept a monistic perspective of the brain and its associated mind functions.

2.5.8 Embodiment Is a Paradigm Shift

Embodiment is a different way of thinking about the importance of PA. Thinking about the human body as of the environment instead of being part of the environment has profound implications for theory, research, education, health and fitness policies, and how people think about the human experience. “Go with the flow” is a more accurate way to think about PA than “Do your exercises now and your math later.” The body is not divorced from the rest of reality but rather is of that reality.

2.5.9 Human Flourishing as Embodiment Is an Empirically Observable Proposition

Human flourishing is about “human embodiment as the ground of human existence (Whitehead, 2019d, p. 275).” Human flourishing is the ultimate end of human conduct but also concerns itself with understanding and valuing the means to that end (Durden-Myers et al., 2018). In line with Whitehead’s phenomenological thought, humans create themselves as embodied beings through embodied interaction with the world (Whitehead, 2019d).

2.6 Physical Activity Is the Human Evolutionary Heritage

2.6.1 Behavior Is Shaped by Evolutionary Natural Selection

Natural selection designs the physiology of human bodies, including the organs. The brain is as emphatically an organ as is the heart, lungs, and kidneys. The behavior of each organ is shaped by the DNA-coded design of that organ. Hearts pump blood, lungs absorb oxygen, and kidneys filter blood, all commensurate with the design of the respective organ. Brains record, store, manipulate, and generate information and patterns of information.

Even social behavior is shaped or optimized by evolution, just as biomechanical optimization sculpts the size of a giraffe’s heart (Sapolsky, 2018). Animals do not behave for the

good of the species; They behave to maximize the number of copies of their genes passed into the next generation (Dawkins, 1976).

Locomotion is circumscribed by the design of the vehicle. Behavior is shaped by the design of the brain. Some vehicles are faster because they were designed to be faster. Some animals are smarter because the brains of their ancestors were selectively favored for their intelligence. Brains do not cause behaviors, but they favor and circumscribe propensities.

2.6.2 Cognitive Executive Functions Evolved as Adaptations for Movement

Movement is the single most important expression of PL. Whitehead is adamant that "humans rely on movement potential to stay alive. To be is to move" (Whitehead, n.d.). Movement is a convenient shorthand for operationalizing thoughts and discussions about PL, but PL is not synonymous with movement.

"Physical literacy is the cornerstone of both participation and excellence in physical activity and sport. Individuals who are physically literate are more likely to be active for life" (Sport for Life, 2019).

Hominid cognition is a collection of information-processing programs that evolved in the Pleistocene to solve the adaptive problems regularly faced by the hunter-gatherer ancestors of humans; problems such as mate selection, language acquisition, cooperation, and sexual infidelity (Barkow et al., 1995). If so, then, "[W]hy do we [humans] and other animals have brains?" (Wolpert, 2011, 0:15).

Brains evolved to produce adaptable and complex movements. Sensory, memory, and cognitive processes either drive or suppress future movements (Wolpert, 2009; 2011, 1:15). The same brain that evolved in adaptation to physical movement is the brain that executes executive functions of working memory, mental flexibility, and self-control. When K-12 teacher Heather

Gardner (2017) involved her students in “games for developing confidence and competence in physical activity” to develop “fundamental movement skills” (Gardner, 2017), she engaged students in games that cultivated cognitive development because those faculties reside in the cerebral cortex that evolved for movement.

2.6.3 Embodiment Is Brain with Body Interacting with Experience and Environment

Biologically and holistically, PL describes the embodiment of the brain with the body. For Homo sapiens, extensive movement is a necessity and not a luxury for healthful well-being as:

1) Humans' bodies evolved to run hundreds of miles without stopping (Karnazes, 2006; McDougall, 2011).
2) Human persistence hunting worked by chasing prey to exhaustion, sometimes taking days (Liebenberg, 2006, 2008; Raichlen & Alexander, 2020).

Homo sapiens is the proverbial naked ape (Morris, 1967). The lack of fur allows cooling by perspiration. Humans require high levels of exercise to be healthy. For humans, unlike other living apes, “exercise is not optional; it is essential” (Pontzer, 2019b, p. 28).

About seven million years ago, hominins shared their last common ancestor with chimpanzees and bonobos. Four to two million years ago, *Australopithecus* appeared with long legs at the same ratio as modern humans but still mainly ate plants (Rogers & Gibbs, 2014; White et al., 2009).

Modern human brains contain an average of 86 billion neurons (Herculano-Houzel, 2016). Although the human brain only weighs two percent of the body, it alone uses 25 percent of all the energy that a body expends (Herculano-Houzel, 2013, 2:53). The human cerebral cortex, with an average of 16 billion neurons, has more neurons than any other brain (Harari, 2018a; Herculano-Houzel, 2013, 5:51, 8:30). If humans mainly ate raw vegetation like other

primates, humans would have to eat eight to nine hours per day to get enough energy to support their brains (Herculano-Houzel, 2013, 10:20).

Two things happened to allow humans to consume enough energy to support their energy-demanding brains:

1) Human ancestors invented cooking, allowing more energy to be consumed in less time (Herculano-Houzel, 2013, 10:58; Wrangham, 2009).
2) Human ancestors added meat to their diet, a significantly more economical energy source than plants (Pobiner, 2013).

By 1.8 million years ago, prime-aged ungulates were being butchered by hominids (Wrangham, 2009, 2017). The consumption of meat necessitated that human omnivorous ancestors, not unlike carnivores, travel further for food than herbivores. Nearly every organ adapted down to the cellular level. Human VO_{2max} output is four times that of chimpanzees (Pontzer, 2017, 2019b). The human body evolved to hunt by persistently chasing prey for a hundred miles and for days if need be.

The agricultural revolution was a recent occurrence: 11,000–9,000 years ago with the domestication of wheat and goats in south-eastern Turkey, western Iran, and the Levant (Harari, 2018b), a blip of time in evolutionary development. Contemporary human bodies are hunter-gatherers' bodies designed to run vast distances for long periods. For example, Tarahumara natives living in the Copper Canyon have been observed to run 100 miles in less than 24 hours, with races lasting 48 hours (Balke & Snow, 1965; McDougall, 2011).

Accounts of persistence hunting in 1985, 1990, 1998, and 2001 by Kalahari San peoples illustrate that modern hunter-gathers can run down large antelope and kudus by chasing them until the prey drops from exhaustion (Liebenberg, 2008; Lieberman, 2020a). Even urbanized

runners can catch a pronghorn antelope, North America's fastest animal, by persistent chasing (Bethea, 2011). "[T]here is a need to encourage everyone to love being active" (Almond, 2010, p. 129).

2.6.4 Human Thought Is a Function of a Hunter-Gatherer Brain

The *Homo sapiens* brain tripled in size in the last 1½ million years (Herculano-Houzel, 2016). *Homo sapiens* evolved from 7 million year-old tree-dwelling apes to become bipedal, persistence hunting, ultra-marathon running, naked apes chasing prey over savannas until prey dropped from exhaustion.

The brain's evolution, in concert with the rest of the body, evolved "propensities," or motivations to do one thing rather than another, to prefer one response over another, to confer euphoria rather than disdain when running extended distances, to favor ways of thinking one way over another that increased fitness to survive and reproduce. "With each new mechanism that is added to the mind, an organism can perform a new task" (Buss, 2019b, p. 35).

2.6.5 The Sedentary Brain Is a Hunter-Gatherer Brain

The human hunter-gatherer brain evolved in concert with the hunter-gatherer body. It takes more brain resources to be physically active than sedentary. In an approach-avoidance task study at the University of British Columbia, using electroencephalography (ECG) to measure cortical resources, researchers found that it took far more brain resources to move toward physically active avatar images than toward sedentary images (Newman & Chacos, 2018). Matthieu Boisgontier, who led the study with Boris Cheval, stated, "To me, these findings would seem to indicate that our brains are innately attracted to being sedentary. …The results make sense from an evolutionary standpoint" (Reynolds, 2018, para. 23). "Conserving energy was necessary" for humans as a species (Reynolds, 2018, para. 25). Dr. Boisgontier further explained

that the fewer calories that atavistic humans burned, the fewer they had to replace at a time when food was not available (Reynolds, 2018b).

2.6.6 The Hunter-Gatherer Brain Is a Phenomenological Brain

Intuitive judgments rely upon basic assessments shaped by human brain-body evolution as described below by Kahneman (2011):

> [Intuition] has been shaped by evolution to provide a continuous assessment of the main problems that an organism must solve to survive. …The questions are perhaps less urgent for a human in a city environment than for a gazelle on the savannah, but we [humans] have inherited the neural mechanisms that evolved to provide ongoing assessments of threat level, and they have not been turned off (Kahneman, 2011, p. 90).

Judea Pearl is a Turing award-winning computer scientist and engineer. His 2019 commentary could have been lifted from a Heidegger lecture:

> Eventually, to get to consciousness, you apply what you understand about the world to yourself, and you look at yourself as one of those factors that's called the neutral factors, operating in the world, and now everything that you learn about the environment applies to you as an agent within this environment (Pearl, 2019, @ 1 hour 51 min).

2.7 Discussion

When the authors of this article initially read Margaret Whitehead's definition of PL, we immediately thought, "Somebody finally got it right." We empathized with Whitehead's (2010a) despair that "the importance of movement development in early childhood was being forgotten. The focus…was directed principally towards the development of language, numeracy, and social skills" (Whitehead, 2010a, p. 3).

The introduction to human evolutionary biology described in this article came from the first author's experience in his undergraduate years when he read *Mankind Evolving* (Dobzhansky, 1970). Today, few scientists debate the statement: “Nothing in biology makes sense except in the light of evolution” (Dobzhansky, 1973, p. 125).

Whitehead (2010c) described embodiment as “the potential individuals have to interact with the environment via movement” (Whitehead, 2010e, pp. 202-203). Physical literacy is now generally recognized as being about movement “with competence and confidence in a wide variety of physical activities that benefit the healthy development of the whole person” (James Mandigo et al., 2009, p. 28). We offer the hunter-gatherer paradigm as an empirically testable, evidence-based explanation that holds that, for humans, exercise is essential and not an elective for human health (Lieberman, 2020b; Pontzer, 2019b). This is a necessary, though perhaps insufficient, condition for achieving “embodiment.” Phenomenology is not needed. Existentialism is not needed.

2.8 Conclusion

In our understanding of the power and efficacy of PL, philosophies such as existentialism and phenomenology have been superseded by science, by empirical evidence that the mind is a function of the brain and not capable of existing independently of it, and the proposition that PA and PL are a sine qua non to being human.

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Chapter Three: Enjoyment of Interactive Cycling While Exergaming

Life is like riding a bicycle.

To keep your balance, you must keep moving.

- Albert Einstein

"Beim Menschen ist es wie beim Velo. Nur wenn er faehrt, kann er bequem die Balance halten." – Albert Einstein, written in a letter to his son Edward on February 5, 1930. A literal translation is: "It is the same with people as it is with riding a bike. Only when moving can one comfortably maintain one's balance." Courtesy of Barbara Wolff, Einstein Archives, Hebrew University, Jerusalem. – Source - https://quoteinvestigator.com/2015/06/28/bicycle/

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This manuscript is based upon Donaldson, G. D., Sheehan, D. P., Boyd, J., & Katz, L. (2022*). Older Adult Enjoyment, Perceived Effort, and Actual Effort While Riding Interactive Stationary Bikes in Different Virtual Levels of Chase-Based Exergaming Interfaces*. Faculty of Kinesiology. University of Calgary. Submitted to the *Journal of Aging and Physical Activity*.

Abstract

This was a study of the motivation of enjoyment and effort with exergaming while cycling to incentivize engagement in physical activity and mitigate the inertia of sedentary behavior. An experimental, randomized, comparative trial was used to examine the impact of enjoyment, perceived effort, and actual effort among a sample of 42 adults ≥ 65 (N=22 males, N=20 females). Participants rode exergaming stationary cycles first while playing exergames without an extended reality interface and then with one, either a Monitor or a virtual reality Headset. A two-way Mixed ANOVA was used to analyze enjoyment, perceived effort, and actual effort. Results showed that enjoyment and perceived effort – but not actual effort – were greater while riding a stationary cycle when engaged in exergaming than when not engaged in exergaming. Enjoyment and perceived effort were similar for interfaces. Exergaming inspired enjoyment and did so equally with either a Monitor or Headset.

Keywords

Physical Activity, Virtual Reality, Enjoyment, Perceived and Actual Effort, Exergaming.

3.1 Background

An examination of more than 200 meta-analyses and studies found that physical activity (PA) is associated with a significant reduction in mortality (Gaesser & Angadi, 2021). The World Health Organization (WHO; 2020) recommends that all adults spend 150-300 minutes weekly of moderate-intensity aerobic PA, or 75-150 minutes of vigorous-intensity aerobic activity, or an equivalent combination, as well as two or more sessions of moderate muscle-strengthening activity. However, most adults ≥65 do not meet the WHO guidelines (Jefferis et al., 2014). The objective for healthy aging has shifted from the absence of disease to the functional ability of older people to do what they value, including mobility to complete daily tasks and participate in activities (World Health Organization, 2021). Engaging in PA while eschewing sedentary behavior (SB) is essential for healthy aging and reducing multimorbidity in older adults (Bauman, 2004; Christofoletti et al., 2021; Chudasama et al., 2019; Ramsey et al., 2021).

3.1.1 The paradox of Physical Activity

Physically active and sedentary behaviors reflect different but complementary survival adaptations. Together, they have been called the paradox of physical activity (Cheval & Boisgontier, 2020). Humans have an "endurance runner" phenotype adapted for survival in wilderness environments, suited to hunting and gathering subsistence strategies that demand traversing long distances in search of food (Mattson, 2012; Raichlen & Alexander, 2020). While the propensity for SB appears to be hard-wired (Speakman, 2020), preindustrial people were adapted to environments that few humans now occupy, and humans now inhabit urban environments that did not exist before agricultural cultivation (White et al., 2009).

It has been argued that humans are averse to exercise, even though the human body requires copious PA to optimize a long, healthy lifespan (Lieberman, 2020; Pontzer, 2019). Lieberman suggests that hunter-gatherers survived "by not foolishly squandering scarce calories on unnecessary activity. … In fact, compared with other mammals, humans might have evolved to be especially averse to exercise" (Lieberman, 2020, p. 41). He argues that "the evidence suggests that humans are more averse to needless physical activity than many other species because we evolved an unusually expensive way of increasing our reproductive success from an unusually low-energy-budget ancestor" (Lieberman, 2020, p. 46). Lieberman refers us to a comprehensive review of research that tested interventions designed to entice non-exercises to get moving, at part F, chapter 11 of Physical Activity Guidelines Advisory Committee (2018), Physical Activity Guidelines Advisory Committee Scientific Report (2018).

3.1.2 Biology of Motivation to Engage in Physical Activity

PA is any bodily movement performed by skeletal muscles that expend energy (Caspersen et al., 1985; Galvao et al., 2021; Lieberman, 2020; Träff et al., 2017). SB expends energy equivalent to sitting or reclining ≤1.5 METs (metabolic equivalents of task; (Dontje et al., 2018; Galvao et al., 2021; Tremblay et al., 2017). A MET is the energy used while resting quietly for one minute (Hall, 2008). PA ranges from 1.5 METs expended during SB through vigorous activities like hiking up a hill (MET > 6.0) to intense activities such as all-out sprinting or bicycling (MET >16); (Hall, 2008).

Motivation is "any internal process that energizes, directs, and sustains behavior" (Reeve, 2016, p. 31). Hormesis is an adaptive biological response of cells and organisms to moderate non-toxic challenges such as PA (Calabrese & Mattson, 2017). Psychiatrist and Stanford professor Dr. Anna Lembke studied the biology of motivation from a neuroscientific perspective.

"We are all wired to approach pleasure and avoid pain, and that is what has kept us alive in a world of scarcity" (Lembke, 2021b, 1:03:28). PA increases dopamine, serotonin, norepinephrine, epinephrine, endocannabinoids, and endogenous opioid peptides (Lembke & Raheemullah, 2019; Linke & Ussher, 2015; Lynch et al., 2013). The brain's most important reward pathway is the mesolimbic dopamine pathway (Nestler Lab of Molecular Psychiatry, 2021).

Researchers believe that dopamine is the essential molecule of motivation or "wanting" and distinct from pleasure or "liking" (Lembke, 2021a; Nguyen et al., 2021). Rats bioengineered to have no dopamine experienced pleasure when food was placed in their mouths, but they starved to death rather than retrieve food when set a body length away (Kringelbach & Berridge, 2012). Pleasure is not wanting (Kringelbach & Berridge, 2012).

The brain uses the neurotransmitter molecule dopamine to maintain homeostasis (balance) between pleasure and pain. PA is associated with motivation regulation through dopaminergic signaling in the reward pathway (Lembke, 2021a; Lynch et al., 2013). PA prompts the brain to release dopamine, allowing electrical signals from pre-synaptic neurons to communicate to post-synaptic neurons in the brain's reward pathway (Lembke, 2021a, p. 49). When more dopamine is released, pleasure is experienced. Pleasure is more enduring when the dopamine is a secondary effect rather than the initial stimulus, resulting from something that is effortful such as PA (Lembke, 2021a).

Pleasure and pain are co-located in the brain. Chocolate, gambling, sex, or cocaine experiences trigger a surge in dopamine with commensurate sensations of pleasure. Seeking the physiologic equilibrium of homeostasis, dopamine subsequently down-regulates, leading to pains of craving, anxiety, or depression. Hunger, exercise, extreme heat, or cold triggers a waning of

dopamine with commensurate pains. Subsequently, again seeking homeostasis, dopamine up-regulates, leading to pleasures of contentment, enjoyment, or euphoria (Lembke, 2021a).

Lembke (2021b) describes homeostasis metaphorically as a teeter-totter with a scale in the middle. When pleasure is experienced, dopamine tips the teeter-totter to the side of pleasure. The more it tips, the more we experience pleasure. “Dopamine’s ancient role in physical movement relates to its role in motivation: to obtain the object of our desire, we need to get it” (Lembke, 2021a, p. 151).”

3.1.3 Psychology of Motivation to Engage in Physical Activity

Motivation factors can be intrinsic or extrinsic (Ryan & Deci, 2017; Wasserman & Wasserman, 2021). Extrinsic motivations drive behaviors to obtain ulterior rewards such as money, grades, or status, whereas intrinsic motivations drive behaviors that are desired end states in and of themselves (Kruglanski et al., 2018). An intrinsic activity is its own reward (Laran & Janiszewski, 2011), such as enjoyment, interest, and satisfaction (Wasserman & Wasserman, 2021). An intrinsic activity is its own reward (Laran & Janiszewski, 2011), such as enjoyment, interest, and satisfaction (Wasserman & Wasserman, 2021). As a psychological construct, motivation can be inferred subjectively by self-report and objectively by expended effort (Wasserman & Wasserman, 2021).

3.1.4 **Single Processing Theory**

Single processing theories treat SB as physical inactivity, drawing upon motivational theories, such as Self-Determination Theory (SDT; Deci & Ryan, 2008; Kooiman & Sheehan, 2015a; Ryan & Deci, 2017). SDT predicts well-being and performance from autonomous motivation. Autonomous motivation can be intrinsic when doing something for enjoyment, or extrinsic when an external reward or request becomes internalized as part of one's self-identity

(Brainwaves Video Anthology, 2017). Intrinsic motivation is the most autonomous form of motivation It acts for the inherent enjoyment of the activity involved. It has been argued that long-term health behavior change is less likely when driven by external forces such as guilt, shame, reward, or punishment (Ng et al., 2012) and therefore intrinsic motivation is one of the most important factors in maintaining exercise over time. SDT predicts that sustained exercise is most likely when a person has both intrinsic motivation and internalized extrinsic motivation (Ryan & Deci, 2007). An example of internalized extrinsic motivation to exercise would be acceptance of rigorous daily training because an individual comes to internalize a high valuation of the external regulations that impose the training regime.

Single processing theories that attempt to explain physical inactivity fail to recognize SB as a distinctly different behavior. SB is not synonymous with physical inactivity. Even physically active people are at higher risk of illness if they live an otherwise predominantly sedentary lifestyle. For example, adults who satisfy WHO daily PA requirements still risk metabolic syndrome with increased sitting time (Ekelund et al., 2016; Madden et al., 2021; Whipple et al., 2021), which may be mitigated by activities such as multiple four-second sprints on a stationary cycle throughout the day (Satiroglu et al., 2021)

3.1.5 **Dual Processing Theory**

Dual processing theory treats PA and SB as separate processes. SB is viewed as distinct from physical activity or physical inactivity and as an independent predictor of metabolic risk even if an individual meets current PA guidelines (Booth & Lees, 2007; Dutheil et al., 2020; Panahi & Tremblay, 2018).

Dual processing theory explains PA engagement in terms of energy expenditure and energy conservation as separate processes. For example, PA and SB predict that enjoyment or

displeasure experienced during PA engagement can influence subsequent decisions for engagement in PA (Ekkekakis, 2017). PA requires effort and the amount of energy expended, the actual effort, does not usually correspond to that effort's subjective difficulty, or perceived effort (Massin, 2017; Preston & Wegner, 2009). Actual effort is therefore distinct from perceived effort (Steele, 2021).

3.1.6 Gaming Interfaces

Historically, variations in gaming interfaces allowed for personalized preferences of gaming engagement. Mechanical pinball machines in the mid-twentieth century were early precursors of computer gaming. Atari's *Pong* ushered in the Video Arcade Machine (VAM) in 1972 (Kooiman & Sheehan, 2015b). Later, in the twenty-first century, Project CARS (Slightly Mad Studios, 2016) and DiRT Rally (Codemasters, 2016) offered popular game simulations that integrated real-world hardware of a steering wheel, gear shifting handle, and floor pedals (Guillemot Corporation S.A., 2021; Logitech Gaming, 2021).

Exergaming is a subset of computer gaming and involves technology-driven physical activities that require participants to be physically active (Witherspoon, 2013) using extended reality (XR) interfaces. XR is an “umbrella term” that describes digital technologies that extend perceptions of reality without creating the actual physical entities that they simulate (Qualcomm Technologies Inc., 2022). Exergame media now includes video (Chao et al., 2015), audio and tactile (Morelli et al., 2010; Morelli et al., 2011), augmented reality (Qin, 2021), virtual reality (VR, Khundam et al., 2021; Stranick & Lopez, 2021), and robotic exoskeleton (Bulea et al., 2017; Demoe et al., 2020; Graser et al., 2021). For example, the *Dance Dance Revolution* (1998) game combined speakers, a dance platform, and a monitor. Another example is *Beat Saber*, the bestselling VR exergame in history, sold four million copies and 40 million in-app song

purchases by 2021 (Smith, 2021). It is a VR rhythm game that requires the player to slash small cubes that fly towards them in rhythm to the music. Exergaming heightens the enjoyment of PA (Farrow et al., 2018; Farrow et al., 2019; Khundam et al., 2021; Qin, 2021; Ryan et al., 2006).

Farrow et al. (2018) reported a partially randomized cross-over study with four conditions that compared mean power output and enjoyment across four conditions: riding in blank mode without enhancement, in track mode while VR exergaming, in ghost mode while racing against a participant's past performance, and in hard mode by increasing the resistance. Enjoyment was higher for track than blank mode but there were no other differences for enjoyment. Mean power output for track was higher than ghost, and higher for hard than ghost, but there was no difference for between track and blank. These findings showed that VR-exergaming can increase enjoyment while cycling, and that racing against your ghost may increase intensity of VR-cycling.

3.1.6.1 Stationary Cycling as a Safe Exergaming Interface

Cycling is a non-weight-bearing, low-contraction exercise that contrasts with the weight-bearing, high-impact forces in long-distance running (Sandbakk et al., 2021). A relatively safe PA for sedentary adults is the less impactful stationary cycling. As sedentary adults tend to be frailer, physically challenged, and suffer from chronic disease more often than frequently active adults (Whipple et al., 2021), stationary cycling offers multiple unique benefits to combat these issues. A stationary cycle in the home is inherently more convenient and controllable than outdoor riding with unpredictable weather, and avoids risks of problematic road traffic. A stationary cycle may also accommodate user needs with auto-adjustment of resistance by heartbeat rate. Riding in the home environment is safe given the absence of vehicles or pedestrians; a stationary bike resists tipping while the user may attend to visual media on a

monitor or listen to music with a headset without the distraction of needing to navigate over terrain.

The 1986 CompuTrainer by RacerMate, an electronic bicycle trainer with Commodore 64 motivational, interactive software displaying cadence and speed on a monitor, may have been the first computerized exergame (Cataldo & Alic, 2017; Thien, 2013). Today, there is a large assortment of indoor exergaming cycling options. Consumers could select a stationary interactive fitness bike with integrated exergaming software displayed on a monitor (Interactive Fitness, 2021), a road bike with an indoor trainer (Wahoo Fitness, 2021a) running interactive gaming software (Zwift Inc, 2021) on a monitor, and virtual exergames displayed inside a headset (Brook, 2020a, 2020b; Holodia, 2021; VirZOOM, 2021) when riding a stationary bike with a sensor (Magenefitness, 2021; Wahoo Fitness, 2021b) that tracks speed or cadence.

3.1.6.2 Virtual Reality Headsets

In 2018, 78% of American households owned a home computer (Martin, 2021), and 96.2% had a television in 2020 (The US Nielsen Company, 2020). Until 2019, media for household VR headsets were tethered to and relied upon as expensive "gaming computers" for media processing and storage. Then, in May 2019, the Oculus Quest was released, a self-contained VR headset (no external computer needed) costing 400 USD. Currently, exergaming literature does not report comparisons of enjoyment between monitor and headset experiences, the technologies of which present fundamentally different participant experiences. A monitor displays two-dimensional (2D) imagery, whereas a headset displays panoramic (360°) imagery. A monitor viewpoint is alien, observing events from outside, whereas a headset viewpoint is immersed within the environment. Headsets support six "degrees of freedom," the number of movements tracked simultaneously in a virtual space: three rotational head movements - rolling,

pitching, yawing, and three directional body movements - elevating, strafing, surging (Meicho, 2019).

3.1.7 Research Gap

A great deal has been written about older adults' healthy and active lifestyles (Cunningham et al., 2020; Lim et al., 2021; Loef & Walach, 2012; Tsai et al., 2020), but less is known about the how new exercise technologies can be used to mitigate SB by integrating practices of PA into the daily routines of older adults. Specifically, it is unclear whether and to what extent the use of VR may enhance enjoyment motivation. A great deal of current literature and research has focussed on exergaming and VR exercise with younger people. Yet, little research has considered the role of exercise technologies and how these can be adapted to engage older adults in PA that is safe, accessible, and motivating. As recreational exergaming grows in popularity, it may be a powerful tool to motivate PA engagement in older adults. Those who satisfy WHO's recommendations for brief PA may find those benefits negated with the disproportionate excessive sedentary behaviors of watching television or sitting for extended periods each day. With this need in mind, the present research was undertaken to study exergaming methods and the extent to which these may enhance the motivation of enjoyment of older adults under contrasting conditions.

3.1.8 Aim and Hypotheses

In this study, we examine the efficacy of exergaming to promote the enjoyment of exercise and how this enjoyment differs when two contrasting interfaces are used, a 2D monitor and a 360° VR headset. A secondary objective of the study was to compare the perceived effort and actual effort of stationary cycling when exergaming against when not exergaming, and to analyze these efforts between the two interfaces. We hypothesize that enjoyment of PA in adults

aged ≥65 is greater when riding a stationary cycle while exergaming than when not exergaming. To further understand the impact of exergaming in PA enjoyment, we also hypothesize that when participants ride a stationary cycle, they will enjoy interacting with a 360° VR headset (Headset) interface more than a 2D monitor (Monitor) interface.

3.2 Method

This study investigated participants' response patterns on a group of dependent motivation variables (Enjoyment, Actual Effort, Perceived Effort) under different levels of virtual interfaces (2D Monitor versus 360° VR headset) while exergaming during the absence and presence of exergaming on interactive stationary cycles. This study was an experimental Randomized Comparative Trial (RCT) to determine whether there are differences between enjoyment among adults aged ≥65 in different levels of virtual interfaces while exergaming and, if so, whether the different measures of enjoyment are associated with the different interfaces.

3.2.1 **Participants**

This study involved a sample of 40 participants. Eligible participants were required to be fluent in English (reading and writing), be able to ride a bike comfortably, and be aged ≥ 65. Based on these inclusion criteria, we recruited 43 adults from email invitations sent to the first author's networks of friends and colleagues. (See Appendix A for Recruitment Poster.) Participants were screened using the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire (Balady et al., 1998) (See Appendix B.) to ensure no heart or health issues that could be exacerbated by riding a bike. All participants provided written informed consent, and the Conjoint Health Research Ethics Board at the University of Calgary approved this study. (See Appendix C).

Due to a software malfunction, data were lost for one female participant. Most participants (88%) were university-educated, married, retired professionals (see Table 2). All participants were independently mobile, able to attend sessions without aid, and did not smoke cigarettes; 43% seldom or never imbibed, while 57% imbibed several times weekly.

Table 2 *Descriptive Statistics: Gender, Age, Martial Status, Education, and Income*

Category	Variable	Male	Female	(n)	%
	Gender	22	20	42	100%
	65-69	3	6	9	21%
	70-74	7	9	16	38%
Age	75-79	7	3	10	24%
Md = 73.5, $\overline{x}$ = 74.5	80-84	3	0	3	7%
	85-89	1	0	1	2%
	90-92	1	2	3	7%
	Married	19	11	30	71%
Marital Status	Widowed	1	5	6	14%
Mode: Married = 71% (30)	Divorced	0	3	3	7%
	Single	2	1	3	7%
	High School	1	4	5	12%
Education	2-3 Years	3	7	10	24%
Mode: Graduate Degree = 40%	4 Years	8	2	10	24%
	Grad Degree	10	7	17	40%
	$21k - $40k	5	5	10	24%
Income (Canadian Dollars)	$41k - $60k	6	2	8	19%
	Over $60k	6	4	10	24%
	No Response	5	9	14	33%

The optimal sample size was calculated with α=0.05, β=0.20, power = 0.80, range = 56, σ = 14, Δ = 8.861. We estimated the standard deviation to be σ = 56/4 = 14, approximated from the "range rule" when applied to the total possible score on the Mullen *Older Adult Physical Activity Enjoyment Scale* (Mullen et al., 2011). The derived value of Δ=8.861 was the difference

found in a pilot between the adjusting means of two groups on the Mullen *Older Adult Physical Activity Enjoyment* Scale (Mullen et al., 2011). (See Appendix D for details of an informal "Friendly Pilot" conducted in September 2018 that was used to test the study's equipment, apparatus, and process.)

3.2.2 Procedure

Data were collected from July 2019 through November 2019. Forty-two participants were each randomly assigned to one of two groups. Each group performed two rides of five minutes each: first while riding without exergaming, then while simultaneously riding and exergaming. A previous pilot project found that 5 minutes was sufficiently long to measure the dependent variables: enjoyment, perceived effort, and maximum effort as maximum heart beats per minute. Each participant played a single exergame during their second ride, so they were only exposed to one interface during the study. One group rode the Expresso Interactive Upright S3U Fitness Bike ("Expresso Bike"; see Figure 1) while playing the Dragon Chase Game as displayed on an integrated 2D monitor (Monitor). (See Appendix E for descriptions of the Expresso S3U stationary cycle and the Dragon Chase game that may be played while riding it.) The second group rode the VirZOOM Interactive VR bike ("VirZOOM bike"; see Figure 2) while playing the Thunder Bowl Tank Game as displayed within a Samsung Odyssey 360º, 3D, head-mounted display (Headset). (See Appendix F for descriptions of the VirZOOM VR stationary cycle and the arcade of exergames that may be played while riding it.)

Figure 1 *Expresso S3U Bike & Monitor*

Adapted from *Expresso Fitness S3U Upright Exercise Bike (Remanufactured)*, by Interactive Fitness, n.d., Fitness Superstore (https://www.fitnesssuperstore.com/Expresso-s2u-Upright-Bike-p/s2u.htm). Copyright 2022 by Interactive Fitness. Adapted with permission. (See Appendix G for approval.)

Figure 2 *VirZOOM Bike and Virtual Reality Headset*

Adapted from *Upgrading to VZfit*, by E. Malafeew, 2019, VZfit, (https://virzoom.com/upgrading-to-vzfit/). Copyright 2021 by VirZoom. Adapted with permission. (See Appendix H for approval.)

This study used self-reported enjoyment and expended maximum heart rate effort as inference measures of motivation to engage in cycling when exergaming. A marathon digital timer was used to set the duration of rides to 5 minutes each. After each ride, the participants completed the three dependent self-reported measures: 1) Mullen Older Adult Physical Activity Enjoyment Scale (Mullen et al., 2011) (See Appendix I for the statements comprising the

Mullen Older Adult Physical Activity Enjoyment Scale that participants evaluated after each ride.); 2) SDT Interest/Enjoyment Intrinsic Motivation Inventory Subscale (Ryan & Deci, 2019) (See Appendix J for the statements comprising the SDT Enjoyment Intrinsic Motivation Subscale that participants evaluated before each ride.); and 3) Cleveland Rated Perceived Exertion (RPE) scale (Cleveland Clinic, 2013). (See Appendix K for the Cleveland Rated Perceived Exertion (RPE) scale of 0-10 that participants used to rate their RPE after each ride). For each ride, a dependent measurement of Actual Effort was measured by using maximum heart rate. Maximum heart rate was recorded on the Strava app on the Apple Series 3 Watch. (See Appendix L for a description of research used to validate the Apple Watch Series 3 to record the heart rate of participants as they rode the stationary cycles during the trials). Data was transferred via Bluetooth to an iPhone X and uploaded to a secure Strava account administered by the first author. (See Appendix M for early planning procedure notes on criteria used to choose the exergames used in the trials, the apparatus used for measuring heartbeat and timing rides during the trial, detailed descriptions of the stationary cycles, and the VR headset used by participants.)

3.2.3 Materials

3.2.3.1 Interactive Stationary Exercise Cycles

The Expresso bike housed the processor and software on board with gaming software displayed on an attached 19" monitor. The VirZOOM bike communicated with a host computer wirelessly using Bluetooth. The host computer housed the processor and gaming software displayed inside a VR headset tethered to the computer. The VirZOOM Bike and rider faced the table supporting the computer. The Expresso bike sat adjacent to the VirZOOM bike facing the opposite direction.

3.2.3.2 Exergames

One group played the Dragon Chase Game (Figure 3) on the Expresso (Monitor) bike and the second group played the Thunder Bowl Tank Game (Figure 4) on the VirZOOM (Headset) bike. Both virtual games are strategy chase games whereby the participant chases a target (coin, dragon, or tank), gaining game points by striking the target. The Dragon Chase Game player controls a virtual chariot attempting to touch coins or dragons. In the Thunder Bowl Tank game, the user controls a virtual tank trying to evade and shoot enemy tanks. In both games, the pace of the vehicle (chariot or tank) was determined by the participant's cycling cadence, but the participant could ride at a preferred pace without penalty. Points are not lost for slowness or cessation of pedaling, so participants did not need to experience physical exhaustion. The participant steered the Expresso (Monitor) bike by turning the bike's handlebars left and right. The VirZOOM (Headset) bike was steered by leaning left to turn left and right to turn right.

Shafer et al. (2019) summarized psychological criteria that contribute to variation in sensory conflict levels when users engage with and react to videogames: spatial presence, perceived reality or realism, perceived interactivity, and enjoyment. Spatial presence is the feeling that one is located in the virtual world. Perceived reality is the perception that the virtual environment feels, looks, and sounds real. Perceived interactivity is the extent of mastery that a user feels that they have over the game. Enjoyment is the pleasure a media user experiences because of exposure to a certain media stimulus. They created a chart used to compare three different interactive games: "Minecraft," "Elite: Dangerous," and "Lucky's Tale" (Shafer et al., 2019, p. 4).

The Dragon Chase Game and the Thunder Bowl Tank Game were matched on two criteria: the Shafer et al. (2019) sensory conflict potential criteria (see Table 3) and physical

exertion. Shafer et al. (2019)'s study compared gaming generally and not exergaming in particular. Exergaming involves physical exertion, so physical exertion was also used to select the Thunder Bowl Tank Game as saliently similar to the Dragon Chase Game.

Figure 3 *Dragon Game (Expresso Bike)*

Adapted from *Try and Chase Ken Dunn*, by Interactive Fitness News, 2013 (https://interactivefitnessblog.wordpress.com/2013/10/21/try-and-chase-ken-dunn/). Copyright 2013 by Interactive Fitness. Adapted with permission. (See Appendix G for approval.)

Figure 4 *Tank Game (VirZOOM Bike)*

Adapted from *VZfit Tank level Thunderbowl gameplay*, by VirZOOM Inc., 2019, Vimeo (https://vimeo.com/354105333). Copyright 2019 by VirZoom Inc. Adapted with permission. (See Appendix H for approval.)

Table 3 *Sensory Conflict Potential Criteria Chart*

Interactive Game	Representative Avatar: 1=yes, 0 = no	Point of View (POV): 1=1st Person 0=3rd Person	Movement: 2=Avatar 1=Vehicle 0=Teleportation or 3rd Person follow	Stabilizing Frame of Reference: 1=no, 0=yes	Total Sensory Conflict Potential
Dragon Chase	0	1	1	0	2
Thunder Bowl	0	1	1	0	2

3.2.4 Statistical Analysis

All analyses were performed with the SPSS statistical package (version 26; IBM Corp., Armonk, NY). Three, two-way (2x2) mixed analysis of variances (ANOVA) were used to evaluate the type of interface (Monitor versus Headset) and Gaming (riding without exergaming versus riding with exergaming) on measures of Mullen Enjoyment, SDT Enjoyment, Perceived Effort, and Actual Effort while riding an interactive stationary bike. (See Appendix N for a description of the Two-Way Mixed Analysis of Variance (ANOVA) used in the study.)

3.3 Results

The summary of the mixed ANOVA results for Mullen Enjoyment, SDT Enjoyment, Perceived Effort, and Actual Effort by Type of Interface (Monitor versus Headset) and Type of Gaming (Without Exergaming versus With Exergaming) are presented in Table 4.

Table 4 *Means, Standard Deviations, and Mixed-ANOVA Statistics for Mullen Enjoyment, SDT Enjoyment, Perceived Effort, and Actual Effort by Gaming and Interface*

	Gaming (G)				Analysis of Variance				
Variable	Without Exergaming		With Exergaming						
Interface (F)	*Mean*	*SD*	*Mean*	*SD*	Effect	*F Ratio*	*Sig*	*df*	η_p^2
Mullen Enjoyment									
Monitor	26.90	9.31	44.14	8.08	Gaming	80.831	.001***		.669
Headset	35.00	11.77	44.43	8.80	Interface	2.678	.110	1,40	.063
Total	30.95	11.25	44.29	8.34	G X F	6.932	.012*		.148
SDT Enjoyment									
Monitor	20.35	7.67	41.15	7.86	Gaming	65.945	.001***		.628
Headset	29.24	10.04	3	8.59	Interface	3.569	.0666	1,39	.084
Total	24.90	9.93	40.27	8.19	G X F	7.729	.008**		.165
Perceived Effort									
Monitor	18.33	5.86	29.10	4.37	Gaming	64.100	.001***		.616
Headset	20.19	6.19	27.57	5.334	Interface	.018	.895	1,40	.000
Total	19.26	6.03	28.33	4.86	G X F	2.226	.144		.053
Actual Effort									
Monitor	106.42	24.41	134.32	24.78	Gaming	4.535	.041*		.118
Headset	106.94	17.58	95.94	15.07	Interface	10.531	.003**	1,34	.236
Total	106.67	21.16	*116.19*	*28.23*	G X F	24.034	.001**		.414

Note. N=42. G = Gaming; F = Interface. *p<.05. **p<.01. ***p<.001.

Testing of simple effects for Mullen Enjoyment, SDT Enjoyment, Perceived Effort, and Actual Effort are reported in Table 5 for Gaming and Table 6 for Interface.

Table 5 ***Testing of Simple Results for Gaming***

Variable					95% CI		
Interface	Gaming	MD (i-j)	SE	Sig.	Lower Bound	Upper Bound	η_p^2
Mullen Enjoyment							
Monitor	Without(i), With(j)	-17.238	2.097	.000***	-21.477	-12.999	.9060
Headset	Without(i), With(j)	-9.429	2.097	.000***	-13.667	-5.190	.9230
SDT Enjoyment							
Monitor	Without(i), With(j)	-20.800	2.731	.000***	-26.324	-15.276	.0113
Headset	Without(i), With(j)	-10.190	2.665	.000***	-15.582	-4.799	.2050
Actual Effort							
Monitor	Without(i), With(j)	-27.895	5.452	.000***	-38.975	-16.815	.4350
Headset	Without(i), With(j)	11.000	5.764	.065***	-0.713	22.713	.0970

MD = Mean Difference. SE = Standard Errors. η_p^2 = Eta Squared Effect Size.
CI = Confidence Interval. *p<.05. **p<.01. ***p<.001.
η_p^2 = 0.01 (small effect). η_p^2 = 0.06 (medium effect). η_p^2 = 0.14 (large effect.).

Table 6 Testing of Simple Results for Interface

Variable					95% CI		
Gaming	Interface	MD (i-j)	SE	Sig.	Lower Bound	Upper Bound	η_p^2
Mullen Enjoyment							
Without	Headset(i), Monitor(j)	8.095	3.274	.018*	1.478	14.712	.1330
With	Headset(i), Monitor(j)	.286	2.607	.913	-4.982	5.554	.0003
SDT Enjoyment							
Without	Headset(i), Monitor(j)	8.888	2.801	.003***	3.223	-14.554	.2730
With	Headset(i), Monitor(j)	-1.721	2.575	.508	--6.931	-12.999	.5980
Actual Effort							
Without	Headset(i), Monitor(j)	0.520	7.167	.943	14.045	15.085	.0002
With	Headset(i), Monitor(j)	-38.375	6.938	.000***	-52.475	-24.274	.4740

MD = Mean Difference. SE = Standard Errors. η_p^2 = Eta Squared Effect Size.
CI = Confidence Interval. *p<.05. **p<.01. ***p<.001.
η_p^2 = 0.01 (small effect); η_p^2 = 0.06 (medium effect); η_p^2 = 0.14 (large effect.).

3.3.1 Enjoyment

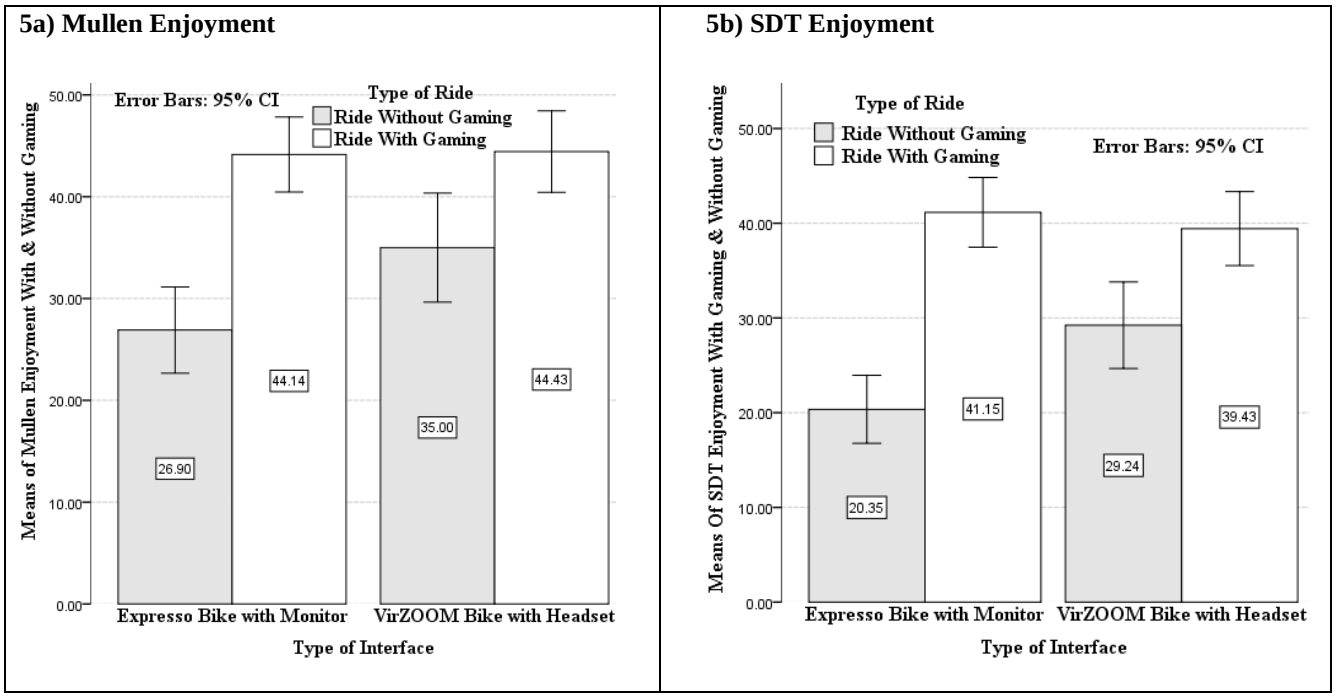
For Mullen Enjoyment, there is a statistically significant Interface by Gaming interaction effect detected ($p<.05$) which indicates that the Interface effect varies with Gaming or Gaming effect varies with the interface. On average, there is a statistically significant Gaming effect ($p<.01$); on average, there is no statistically significant Interface effect.

For SDT Enjoyment, there is a statistically significant Interface by Gaming interaction effect detected ($p<.01$) which indicates that the Interface effect varies with Gaming or Gaming effect varies with the interface. On the average, there is a statistically significant Gaming effect ($p<.01$) and on the average, there is no statistically significant Interface effect.

When riding either bike without exergaming, participants self-reported scores for Mullen Enjoyment and SDT Enjoyment that were significantly higher on the VirZOOM (Headset) bike than the Expresso (Monitor) bike ($p<.05$) for Mullen Enjoyment and ($p<.01$) for SDT. However, when exergaming while riding, there were no significant differences on either bike for Mullen Enjoyment and SDT Enjoyment. The interface effect is significant without exergaming, but not significant with exergaming (i.e., interface effect varies with gaming). Regardless of interface, on average, for both Enjoyments, there is a statistically significant increase with riding while exergaming compared to riding without exergaming ($p<.001$).

Figure 5 provides clustered bar graphs of means and standard deviations for the Type of Interface by Type of Gaming on measures of Mullen Enjoyment and SDT Enjoyment.

Figure 5 *Clustered Bar Graphs of Means and Standard Deviations for the Type of Interface on Measures of Mullen Enjoyment and SDT Enjoyment, With Gaming and Without Gaming*



3.3.2 Enjoyment of Riding Increased When Exergaming

Comparisons of Enjoyment (Mullen & SDT) means displayed in Figures 5 graphically show that the means for Enjoyment with exergaming are significantly higher than are the means for Enjoyment without exergaming for Headset and Monitor, all $p < .001$ separately.

Table 3 shows that, when not exergaming, the riders of the VirZOOM (Headset) bike expressed greater Mullen Enjoyment (mean = 35.00, SD = 11.77) than did riders of the Espresso (Monitor) bike (mean = 26.90, SD = 9.31). Likewise, the riders with the Headset expressed greater SDT Enjoyment (mean = 29.24, SD = 10.04) than did riders with the Monitor (mean = 20.35, SD = 7.67). However, this distinction lessened when participants engaged in exergaming, as evidenced by similar scores for Mullen Enjoyment when using the Headset (mean = 44.43, SD = 8.80) and Monitor (mean = 44.14, SD = 8.08). Similar scores were also determined for SDT Enjoyment for Headset (mean = 39.43, SD = 8.59) and Monitor (mean = 41.15, SD = 7.86).

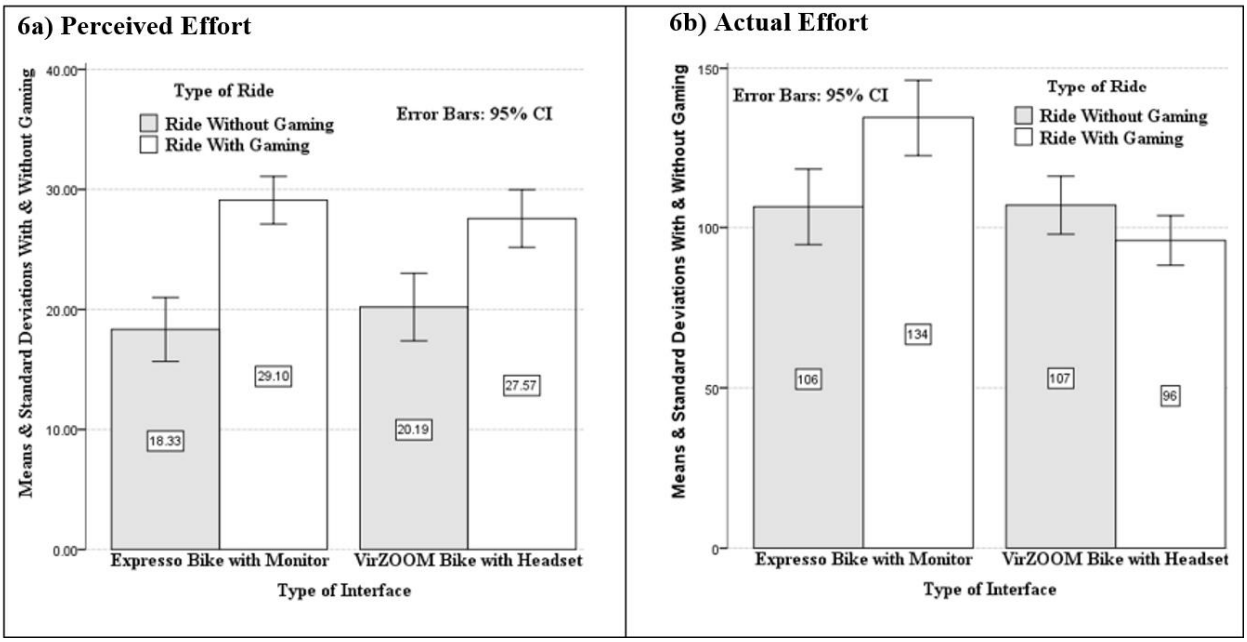
3.3.3 **Perceived Effort**

For Perceived Effort, no statistically significant Interface by Gaming interaction effect was detected. Due to the lack of statistically significant Interface by Gaming effect, it is not necessary to perform testing of simple effects.

3.3.3.1 Perceived Effort of Riding Increased When Exergaming

There was a statistically significant and large effect size of Gaming on Perceived Effort: ($p<.001$). This indicates that there is a significant difference between exergaming and not exergaming on Perceived Effort. The comparison of means displayed in bar graph Figure 6 shows the means for Perceived Effort while exergaming is higher than Perceived Effort without exergaming.

Figure 6 *Clustered Bar Graphs of Means and Standard Deviations for the Type of Interface on Measures of Perceived Effort and Actual Effort, With Gaming and Without Gaming*



3.3.3.2 Perceived Effort When Exergaming Erased Nongaming Differences of Interfaces

As seen in Table 3, when not exergaming, VirZOOM (Headset) bike riders expressed greater Perceived Effort (mean = 20.19, SD = 6.19) than did Expresso (Monitor) bike riders (mean = 18.33, SD = 5.86), but that distinction was not as apparent when participants engaged in exergaming while riding, regardless of the interface used. When exergaming, Monitor users experienced similar Perceived Effort (mean = 29.10, SD = 4.37) to that experienced by Headset users (mean = 27.57, SD = 5.30) when exergaming while riding. Table 3 also shows a modest effect size of Type of Gaming (η_p^2 = .616) and a very small effect size of Type of Interface (η_p^2 = .000012) on Perceived Effort. No statistically significant Interface by Gaming interaction effect was detected.

The net increase in Perceived Effort from riding without exergaming to riding while exergaming was greater with the Monitor interface than with the Headset interface. Figure 6 shows a bar graph of the marginal means for the two conditions. The difference in estimated marginal means is almost identical for the two interfaces when exergaming, regardless of which interface was used without exergaming.

Headset expressed somewhat smaller Perceived Effort than the Monitor with exergaming; however, the magnitude of reversed direction was not large enough to show any statistically significant Interface by Gaming interaction effect.

When riding either bike without exergaming, participants self-reported scores for both Enjoyment and Perceived Effort that were significantly higher on the VirZOOM (Headset) bike than the Expresso (Monitor) bike. However, when exergaming while riding, those differences dissipated on both bikes regardless of whether the interface was Monitor or Headset. Despite the different interfaces, Enjoyment and Perceived Effort increased while riding and exergaming

compared to riding without exergaming. As one participant, comparing manual and VR modes of the VirZOOM bike, observed: “VR is way more enjoyable because you’re concentrating more on the game than on riding.”

3.3.4 Actual Effort

For Actual Effort, there is a statistically significant Interface by Gaming interaction effect detected ($p<.01$) which indicates that the Interface effect varies with Gaming or Gaming effect varies with the interface. On average, there is a statistically significant Gaming effect ($p<.05$), and on average, there is a statistically significant Interface effect ($p<.01$).

The Actual Effort of participants, as measured by maximum heart rate, was about the same with either bike when riding without exergaming but increased significantly when exergaming while riding the Espresso (Monitor) bike ($p<.001$) and decreased when exergaming while riding the VirZOOM (Headset) bike ($p<.01$). There is a statistically significant interface by gaming interaction effect, and interface effect is significant at exergaming ($p<.001$), but not significant without exergaming (i.e. interface effect varies with gaming). Actual Effort increased when the Espresso (Monitor) bike group switched from riding while not exergaming to riding while exergaming. The opposite trend was observed for the VirZOOM (Headset) bike group: Actual Effort decreased when they switched from riding without exergaming to riding while exergaming.

3.4 Discussion

This study tested two extended reality interfaces for exergaming via a 2D screen, a monitor, and a 360^{o} VR headset to explore best practices for engaging adults aged ≥ 65 in PA. The primary objectives were to compare the enjoyment of stationary cycling without exergaming against stationary cycling with interactive exergaming, and to compare the enjoyment of

exergaming on a stationary cycle with two different interfaces, a 2D monitor and a 360° VR headset. Secondary objectives were to compare the perceived effort and actual effort of stationary cycling without exergaming against with exergaming, and to compare these efforts between the two interfaces.

Earlier studies found that exergaming increases the enjoyment of PA engagement (Evans et al., 2021; Farrow et al., 2019; Monedero et al., 2015). The main finding from this study supports these authors' same conclusion. Enjoyment was significantly higher in the case of both interfaces when riding the bike and exergaming than when not exergaming. The increase in Enjoyment while exergaming and engaged in PA was similar regardless of whether the exergaming interface was a detached 2D monitor or a 360° VR headset that fully encompassed the participant's head. The lack of a significant difference in Enjoyment between these two interfaces suggests that the exergaming and not the type of interface induced increased enjoyment. This interpretation is consistent with SDT theory which states that intrinsic motivation, such as enjoyment, induces engagement for its own sake (Collins & Pope, 2021). Enjoyment can also be impacted by neurobiological processes triggered by PA engagement itself, such as the euphoria caused by endogenous endocannabinoids (Muguruza et al., 2019; Siebers et al., 2021). Because exergaming increases enjoyment during PA engagement, it is compatible with neuroscience findings that pleasure is more enduring when the dopaminergic signaling is a secondary effect rather than the initial stimulus, resulting from something that is effortful such as PA (Lembke, 2021a).

Perceived Effort was higher when riding with exergaming than when riding without exergaming regardless of the type of interface. This finding differs from a similar study conducted by Gao et al. (2017) who reported that perceived effort was lower when participants

were riding a VR-based VirZOOM bike versus when riding a traditional stationary exercise bike. They attributed this difference in perceived effort to the enjoyable nature of the VR experience, noting that none of the riders were familiar with the VirZOOM bike. Interestingly, this study was comprised of two 20-minute sessions on each bike whereas in the present study, participants only had two 5-minute sessions. The difference in riding times may have partially affected perceived effort levels.

Actual Effort measured by maximum heart rate was greater with the Espresso (Monitor) bike than with the VirZOOM (Headset) bike. A different chase game played on the two bikes may explain the differences in Actual Effort with the different interfaces between riding without exergaming and riding with exergaming. Success with the Dragon Game on the Espresso (Monitor) bike optimized when the player continued riding quickly, not when they slowed down or stopped pedaling. In contrast, success with the Tank Game on the VirZOOM (Headset) bike incentivized riders sometimes to slow their virtual vehicle to evade enemy tanks. While exergaming, the Actual Effort on the Expresso (Monitor) bike was not commensurate with the Perceived Effort. However, in contrast, the Actual Effort was somewhat less on the VirZOOM (Headset) bike when exergaming than when not exergaming.

3.5 Limitations and Future Studies

There are a few notable limitations to the study. First, a convenience sample was drawn from the first author's known networks of retired university faculty and high school teachers, limiting the generalizability of this research. Second, within this sample, participants ranged in age from 65 to 92 years old, creating a large variance around performance measures, making it less likely to identify statistically significant observations. Third, the two interactive stationary bikes used were similar but not identical which may have influenced Enjoyment. Fourth, it is

possible that exergaming was enjoyable because it was a distraction or entertainment. Future studies should compare the enjoyment of exergaming with other concurrent activities such as reading, singing, playing the game Jeopardy, or listening to a podcast. It is possible that the 5-minute duration of the rides impacted outcomes. Future studies should experiment with varying time durations of rides.

Future studies comparing different interfaces would benefit from using precisely the same bike model and identical exergames programmed for different interfaces. We were unable to locate a single model bike with the same exergame played on both a monitor and VR headset and did not have the budget to generate an ideal setup that would allow all participants to ride the same model of bike and play the same game on both the monitor and VR headset. Instead, we chose two interactive stationary bikes that were similar but not identical and two exergaming chase games, one from each bike, with identical scores on a sensory conflict potential criteria chart. Alternatively, in future studies, all participants could repeat the same trial on the second day, meaning they would ride the bike they did not ride and play the exergame they did not play on the first day. There would be a learning history effect, but this would allow statistical comparison of measures to tease out the impact, if any, from the differences in the two models of bikes and variations of play in the games.

As our study has shown, a 19" monitor and a 360° VR headset were not as crucial for enjoyment motivation as was the presence of exergaming. Research is needed to test the intriguing hypothesis that gaming is more important than an interface for inducing the motivation of enjoyment. Future studies should compare the relative efficacy of increased enjoyment of exergaming through other types of media such as virtual "caves," VR glasses, and interactive

robots. Enhanced enjoyment may accrue from bodily movement while exergaming and not exclusively from the sensory imagery of the exergames.

Future studies should also compare enjoyment with animated interactive exergaming equipment, such as the bikes used in this study, against enjoyment with live and recorded human trainers while using interactive "smart" exercise equipment such as those marketed by Peloton (Peloton Interactive, 2021) and NordicTrack (iFIT Health & Fitness Inc., 2021). These “smart” exercise equipment automatically calibrates resistance to effort and inclination according to pre-recorded terrain, the participant's performance history, and real-time participant heart rate. It would be informative to compare enjoyment motivation of streaming workouts from remote geographical locations (NordicTrack) against streaming studio workouts from NordicTrack, Peloton, Apple Fitness+ (Apple Inc., 2021), FitOn (FitOn Inc., 2021), and Tonal (Tonal Systems, 2021).

3.6 Conclusion

For adults aged ≥65, exergaming while riding an interactive stationary bike is more enjoyable than riding without exergaming. When the participants enjoyed PA, the interactive experience of exergaming while cycling on a stationary bike was more important than whether the display interface was a 2D monitor or a 360° VR headset. For adults aged ≥65, the results of this study support the conclusion that exergaming effectively and significantly increases enjoyment motivation to engage in PA while cycling. Exergaming for adults ≥65 may be an effective tool to improve PA and may not require expensive VR headsets to be engaging.

References - Chapter Three: Enjoyment of Interactive Cycling While Exergaming

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Chapter Four: Managing Physical & Sedentary Behaviors for Life

Fitness is a journey, not a destination.

It must be continued for the rest of your life.

- Dr. Kenneth Cooper,

https://cooperaerobics.com/About/Our-Leaders/Kenneth-H-Cooper,-MD,-MPH-Full-Bio.aspx

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This manuscript is based upon Donaldson, G. D., Sheehan, D. P., & Katz, L. (2022). *Optimize Physical Activity & Mitigate Sedentary Behavior for Life: An Electronic Delphi Study - Retired Teachers Advise Adolescents*. Faculty of Kinesiology. University of Calgary. Submitted to journal *PLOS ONE*, published by Public Library of Science (PLOS).

Abstract

It has been argued that humans generally avoid exercise, preferring to rest and conserve energy, even though their bodies require copious physical activity to optimize a long, healthy lifespan (Lieberman, 2020; Pontzer, 2019). The World Health Organization (2020) recommends that adults get 150-300 minutes of aerobic exercise weekly and minimally two sessions of muscle-strengthening activity. Arguably, adolescents would benefit from adults' advice on optimizing physical activities and mitigating sedentary behaviors over the life course. In the present study, the Delphi Method was used to tap the accumulated wisdom of lived experiences of nine retired teachers aged ≥ 65 years. The Delphi Method is a structured communication technique for obtaining a consensus of advice from a panel of experts. Anonymity is assured so that panel members will not feel inhibited in responding. Anonymity also inhibits the formation of a "herd response" to the questions. The panel participated in a three-round Electronic Delphi study where they advised their 15-year-old selves on managing physical activities and mitigating sedentary behaviors before age 65 to optimize health when aged ≥ 65. This study generated and prioritized 155 assertions grouped into 13 themes, such as avoid addictive substances and injuries when young, lead a balanced life, make activity routine, educate your body, enjoy physical activity, seek companionship and sharing, travel and move in the wilderness, move instead of resting, go it alone, invest in technology and wearables, be selective in friendships, and manage internet technology.

Keywords: Electronic Delphi Study, Physical Activity, Sedentary Behavior, Adolescents, Older Adults, Retired Teachers

4.1 Background

4.1.1 Physical Activity and Sedentary Behavior

Being physically active and limiting resting behavior is essential to human health. In recent years, the objective for healthy aging has shifted from the absence of disease to the functional ability of older people to do what they value (World Health Organization, 2021b), including mobility to complete daily tasks and participate in activities (World Health Organization, 2021a). The World Health Organization (2020) recommends that all adults weekly spend 150-300 minutes of moderate-intensity aerobic PA, or 75-150 minutes of vigorous-intensity aerobic activity, or an equivalent combination, and two or more sessions of moderate muscle-strengthening activity. Physical activity while limiting resting behavior is essential for healthful aging and reducing multimorbidity in older adults (Bauman, 2004; Christofoletti et al., 2021; Chudasama et al., 2019; Ramsey et al., 2021).

Humans generally avoid exercise, even though the human body requires copious PA to optimize a long, healthy lifespan (Lieberman, 2020; Pontzer, 2019), preferring to rest and conserve energy once needed for survival (Lieberman, 2020; Raichlen & Alexander, 2017). One of the principal insights from the Minnesota Starvation Experiment is that "*resting is not just a state of physical activity"* (Lieberman, 2020, p. 37) [Emphasis in the original]. This is a landmark clinical study performed from 19 November 1944 to 20 December 1949 at the University of Minnesota on starvation's physiological and psychological effects. Thirty-six male participants were selected from 2,000 volunteers to lose 25% of their weight over nine months. While the men's bodies wasted away, they became lethargic, their physical activity diminished to a minimum, and their bodies consumed less energy while resting as heart rates decreased by one-third, dropping to 95.8%, and hearts, livers and kidneys shrank by about 17% (Keys, Brožek,

& Henschel, 1950; Keys, Brožek, Henschel, et al., 1950; Tucker, 2006). When energy is scarce, necessary physical activity reduces so that energy can be devoted to survival and reproduction.

Daniel Lieberman (2015) contends that humans historically avoided unnecessary exertion because energy from food was limited and evolved to be unique among primates to being well-adapted for endurance instead of power (Lieberman, 2015, p. 314). “By any standards, exercise is clearly one of the most potent medicines there is” (Lieberman, 2014, p. 16), however, the historical human hunter-gatherer body has had to adapt to a more sedentary lifestyle that has led to “illnesses of civilization” such as cancer, obesity, type 2 diabetes, heart disease, and osteoporosis.

Opposing physically active and resting behaviors reflect different but complementary survival adaptations. It has been called the paradox of physical activity (Cheval & Boisgontier, 2020). Preindustrial peoples were adapted to environments that few humans now occupy (White et al., 2009). Humans inherited an “endurance runner” body adapted for survival in wilderness environments, suited to a hunting and gathering lifestyle that demanded traveling long distances in search of food (Mattson, 2012; Raichlen & Alexander, 2020), yet the desire to conserve energy by resting appears to be hard-wired (Speakman, 2020). A twenty-first-century “hunt” now targets a convenient fridge, cupboard, or bistro, leaving bodies genetically coded to jog marathons daily languishing in front of screens.

4.1.2 A Gap in Longitudinal Perspectives

A great deal has been written about the importance of older adults’ healthy and active lifestyles (Cunningham et al., 2020; Lim et al., 2021; Loef & Walach, 2012; Tsai et al., 2020), but less is known about the background and longitudinal impact of experiences that contribute to

maintaining PA and wellness in later life. What wisdom have seniors deduced from a life of experience between adolescence and later years?

Healthy aging is a lifelong learning journey, and attention needs to be given to factors that promote activity and PL from an early age. The present study investigates the memories and accumulated wisdom of a panel of retired senior high school teachers who interacted daily with adolescents for decades in classrooms, gymnasiums, outdoor pitches, courts, and fields.

4.1.3 Retrospective Longitudinal Study

A retrospective longitudinal study uses data acquired in the past (Portney & Watkins, 2009; Singer, 2015). An obstacle to prospective longitudinal studies is the ongoing commitment of funds and resources to a single project. If senior citizens are involved, some may die during the study (Thomas et al., 2015). This study elicited advice for adolescents based on a half-century of memories and lessons of a panel of senior educators. Panelists were asked to advise their 15-year-old selves on living a healthful lifestyle by optimizing the benefits of physical activities and mitigating damage from sedentary behaviors. “If only I knew then what I know now.”

4.1.4 Delphi Project

The Delphi Method is used primarily when the available knowledge is incomplete or subject to uncertainty (Niederberger & Spranger, 2020). The objective is to identify a consensus by collecting expert-based judgments (Niederberger & Spranger, 2020). A Delphi project convenes panels with expertise that matches specific inquiries. “The Delphi technique does not produce any right or wrong answers or any definitive answers; instead, it produces valid expert opinion” (Keeney et al., 2011, p. 9). Delphi consensus is about wisdom and does not ascertain facts. The Delphi Method has been used in health research to measure health promotion in sports

clubs (Johnson et al., 2020), validate survey instruments that measure the success of community-based research partnerships (Brush et al., 2022), and determine contextual factors of heart failure self-care intervention (Whittal et al., 2021).

Experts contribute informed judgment but do not need standard academic qualifications (Ziglio, 1996). For example, in assessing the quality of hospital care, “both types of expertise (lay and medical) are meaningful for developing quality of care indicators which go beyond narrowly defined clinical criteria” (Ziglio, 1996, p. 15). Another example of a Delphi study sought consensus on military veterans' social isolation and loneliness. “To be an ‘expert’ within this study, participants were either a veteran themselves, or working with veterans, and knew social isolation and loneliness” (Wilson-Menzfeld et al., 2019, p. 14).

A Delphi panel can be selected for homogeneity and heterogeneity. Homogeneity, achieved by selecting panelists from a common culture, helps concentrate focus on the inquiry without superfluous distractions. A heterogeneous panel increases the validity of the consensus by broadening the scope and depth of the panel’s expertise and experience (Duncan et al., 2004; Mead & Moseley, 2001; Mullen, 2003; Powell, 2003; Ziglio, 1996).

In this study, we tapped a novel source of knowledge and wisdom: the curated memories of nine retired senior high school teachers. Each panelist had a half-century of personal life experiences and decades of professional familiarity with adolescents. The advice was based on the distillation of observations and assimilation of data.

4.2 Schedule

The project was administered in February 2022 (see Table 7). The rapid pace promoted commitment and diminished attrition among the panelists. Recruitment was initiated by email and followed up when an email response was not received within 48 hours (see Appendix O and

Appendix P for emails used to recruit panelists). Three questionnaires soliciting feedback on the inquiry were administered. A fourth questionnaire, an extensive demographic questionnaire, was issued to profile the panel. See Figure 7 for a flowchart of the process.

Figure 7 *Flowchart of Delphi Project to Manage Physical Activity & Sedentary Behavior*

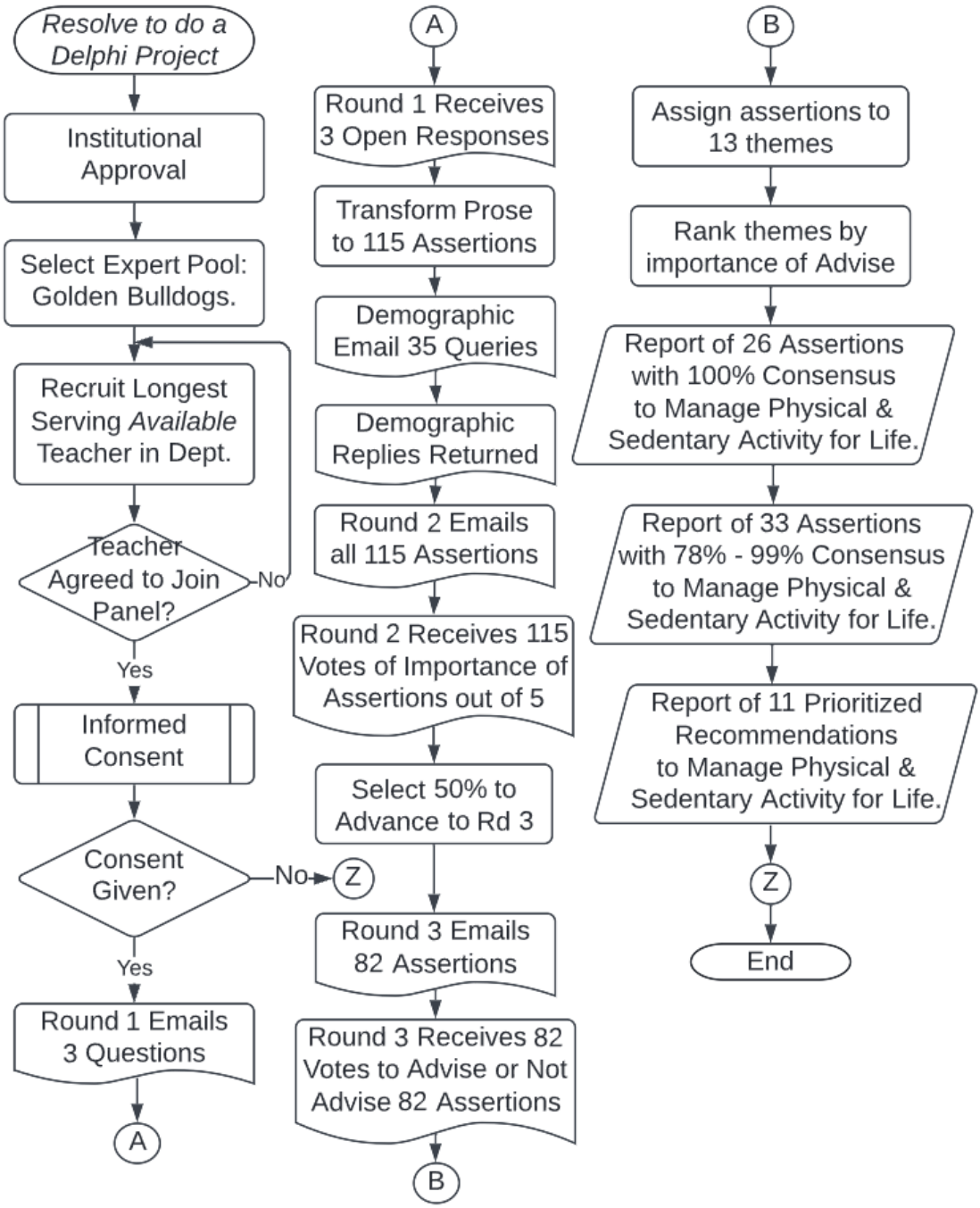


Table 7 *Timetable of Project Phases*

Phase of Study		Time Frame (2022)	Tasks Accomplished
1	Approval	January 7 – January 21	Institutional Approval Sought and Received.
2	Recruitment	January 23 – January 29	A nine member panel was duly constituted.
3	Round 1	January 30 – February 5	Three open-response questions were answered.
4	Demography	February 6 – February 12	Extensive demographic details were gathered.
5	Round 2	February13 – February 19	115 statements each received 1 of 5 choices.
6	Round 3	February 20 – February 26	82 statements each received up or down vote.
7	Appreciation	February 26 – February 28	Deliver gift book (Gupta, 2021)* to panelists.
8	Translation	Month of March	Prepare this article for submission to Journal.

* Gupta, S. (2021). *Keep Sharp: Build a Better Brain at Any Age*. Simon & Schuster Canada.

4.3 Methods

4.3.1 Classical Delphi

An a priori assumption of the Delphi Method is that a group consensus generates a valued opinion. "Project DELPHI" was devised in 1951 by Norman Daley of the RAND Corporation to estimate the number of A-bombs required to reduce munitions output to a prescribed amount. The project achieved a consensus by subjecting experts to questionnaires interspersed with controlled opinion feedback (Dalkey & Helmer, 1963). A Delphi project has four features: anonymity, iteration, controlled feedback, and aggregation of a group response (Dalkey & Helmer, 1963; Keeney et al., 2011; Rowe & Wright, 1999; Skulmoski et al., 2007).

1. *Anonymity* of panelists is the hallmark of a Delphi project. Anonymity removes social pressures from dominant or dogmatic members so that ideas may be evaluated on merit. Anonymity also diminishes herding tendencies.
2. *Iteration*, the repetition of statements over more than one round, allows panelists to change their minds without embarrassment after learning the voting summary of the entire panel.

3. *Controlled feedback* informs panelists of the anonymous opinions of others, which can be a statistical or graphical summary of responses from an earlier round. Controlled feedback is the consensus-building mechanism of a Delphi project.
4. *Aggregation* generates a final round weighting of the panel's judgment.

4.3.2 Electronic Delphi Process

This project was administered electronically as an "e-Delphi" project, administered by emails and online surveys (Keeney et al., 2011). A recent electronic modified Delphi study that developed a measurement tool based on a consensus of perception of health promotion with sports clubs used a similar process (Johnson et al., 2020). In the present study, panelists were invited to participate in three rounds. The first round created a list of items of interest, the second round validated the items based on relevance, importance, and feasibility, and the third round created a list a final list of items grouped by eleven categories.

Four questionnaires were administered. Each questionnaire was preceded by a separate emailed "cover letter" that explained the purpose and mechanics of the questionnaire. The Round 1 questionnaire solicited open-response replies to three generic questions and was administered exclusively by email. The second questionnaire, the demographic questionnaire, gathered demographic data of the panelists and consisted of open-response and objective-type questions with responses collected using Google Forms (Google Inc., 2022). Questionnaires for Round 2 and Round 3 gathered inquiry data and multiple-choice menu selections with responses gathered using Google Forms.

4.3.3 Electronic Software Tools

Email was used for messaging and notifications. Google Forms (Google Inc., 2022) was used to create, edit, present, and retrieve demographic and multiple-choice data. All data was

downloaded to the first author's private desktop hard drive. Statistical Product and Service Solutions (SPSS) Statistics (IBM Corporation, 2013) was used to summarize data statistically. Google Sheets (Google Inc., 2006), a collaborative spreadsheet, was used to organize and display data retrieved with Google Forms. Microsoft Excel (Microsoft Corporation, 2022a) spreadsheet was used to recode textual data fields organized as Google Sheets was used to convert textual data to SPSS type labels. Microsoft WORD (Microsoft Corporation, 2022b) was used to record and sort assertions into groups of thirteen themes. Data generated by SPSS was transferred to 115 different frequency tables constructed in MS WORD, which were used extensively to analyze the Round 2 results and prepare the Round 3 questionnaire. See Table 8 for an example of a frequency table as used in this project.

Table 8 *Assertion Frequency Table*

This is an example of a statement advising physical activity to promote healthful living.			
	Frequency	**Percent**	**Cumulative Percent**
Critically Important	1	11.1	11.1
Important	1	11.1	22.2
Moderately Important	3	33.3	55.6
Not Important	2	22.2	77.8
Irrelevant	2	22.2	100.0

4.3.4 Ethics Approval

This study was approved by the University of Calgary Conjoint Health Research Ethics Board, Ethics ID: REB18-1474.

4.4 Recruitment

4.4.1 Panel Cohort

Nine retired senior high teachers were recruited from a loosely knit organization called the "Golden Bulldogs," which consisted of 167 retired teachers and support staff of an urban senior high school in Western Canada that offers vital academic programs such as the International

Baccalaureate and Advanced Placement as well as opportunities in technical fields and fine arts. Teachers who had taught the longest in each school department were invited to participate. The next longest-serving teacher in the same department was invited when a teacher declined. Nine Golden Bulldogs declined. Eight others accepted invitations to join the panel. This paper's first author, the longest-serving and only available retired Business Education teacher, was the ninth panelist. All participants provided written informed consent. (See Appendix Q for the participant consent form that lists the investigators, background and purpose of the study, measures taken to ensure the privacy of the collected data, and signatures of the participant and witness acknowledging that the participant is satisfied with the conditions of participation.)

The nine panelists collectively held 20 university degrees, had 302 years of classroom teaching experience, and had coached eleven different sports for 303 seasons. All panelists were aged ≥ 65, received teaching and government pensions, and lived in their own homes with a partner. Eight lived in a single-detached house and one in a semi-detached home. None currently smoke, seven had exercise apparatus in their home, and six wore fitness monitoring devices.

Selection for homogeneity by age ≥ 65 ensured that all panelists had more than half of a century of lived experiences beyond the 15-year-old adolescent selves they were tasked to advise, 15 being the typical age of students entering their first year in the panelists' high school. Selection for extensive practice at a single school increased the likelihood that the nine panelists subscribed to a subculture of shared norms and values.

4.4.2 Invitations to Participate

Recipients were advised that each survey could require 90 minutes to complete. Recipients were asked to advise their 15-year-old selves on two fundamental questions.

1. What attitudes and practices best motivated engagement in physical activity?

2. What attitudes and practices best motivated mitigation of sedentary behavior?

Anonymity was assured by hiding email addresses in the “Bcc” email window. Recipients were familiarized with Delphi-type instruments and analyses by being sent a copy of appendices from an unrelated Delphi study (Wilson-Menzfeld et al., 2019) that contained questionnaires and findings of a Delphi report concerning military veterans.

4.4.3 Demographic Data Collection

Google Forms was used to distribute a demographic survey of 35 multiple choice and short answer questions that could be completed in less than one hour. Upon electronic submission and receipt of the completed demographic survey, a copy of the completed survey was automatically emailed to the panelist. Demographic data are summarized in Table 9.

Table 9 *Self Reported Demographics of the Panel Members (n=9)*

Demographic	Parameters							
Gender	Female				Male			
	3				6			
Age	Range		Median		Mode (3 panelists)			
	65-77		72		77			
Years Taught	Career Years Taught				Delphi School Years Taught			
	Total	Range	Median	Mean	Total	Range	Median	Mean
	302	30-40	36	33.6	204	17-28	24	22.7

High School Subjects Taught

Subjects Taught Upon Retiring	Other Subjects Taught During Career
Business Education English, Guidance Mathematics, Science Physical Education Second Languages Social Studies Special Education.	Accounting, Art, Biology, Computer Science, Computer Applications, Chemistry, Counselling, Economics, Finance, French, Geography, German, History, Language Arts, Law, Outdoor Education, Psychology, Recordkeeping, Sociology, Typing.

Table 9 *Self Reported Demographics of the Panel Members (n=9)*

Demographic	Parameters					
Number of Sports Seasons Coached During Careers	Football (72), Basketball (90), Track & Field (46), Soccer (39), Swimming (15), Badminton (12), Wrestling (11), Rugby (7), Distance Running (6), Volleyball (4), Field Hockey (1) = Total 303 Sports Seasons.					
Degrees Earned	Undergraduate			Graduate		
	Bachelor of Arts = 1			Master of Arts = 2		
	Bachelor of Science = 3			Master of Science = 2		
	Bachelor of Education = 7			Master of Education = 1		
	Bachelor of Kinesiology = 2			Other Post-Graduate = 2		
Birthplace	Alberta		Germany		England	
	6		2		1	
Married or Partner	All nine panelists shared a long-term committed relationship with a partner.					
Housing	Single-Detached			Semi-Detached		
	8			1		
Number of Occupants in Home Including Self	Two Occupants			Three Occupants		
	8			1		
Employment Status	Retired		Employment Part-Time		Full-Time Student	
	7		1		1	
Self Reported Fitness	Currently			At Age 15		
	Perfect	Good	Poor	Perfect	Good	Poor
	2	6	1	6	2	1
Smoking Tobacco	Never Smoked			Smoking Now		
	5			0		
Workout Apparatus in the Homes of the 9 Panelists	Stationary bike (4), Elliptical (4), Treadmill (2), Rowing Machine (1), Dumbbells (7), Home Resistance System (3), Resistance Bands (5), Balance boards (2), Yoga Mat (1), Barbells (1), No Apparatus (2).					
Fitness Monitoring Devices in the Homes of the 9 Panelists	Smart Watch (6), Smartphone (3), Heartbeat Monitor (3), Blood pressure monitor (3), Oximeter (1), Smart Ring (1).					

4.5 Round 1

4.5.1 Email Cover Page

In Round 1, four emails were distributed to panelists. A “cover page” email explained that the purpose of Round 1 inquiry was to share their life course wisdom by answering three open-ended questions (see Figure 8). The other three emails each included one of the following questions. A preamble was included with each question to remind the panel of the paradox that physical activity is essential for healthful aging and reducing multimorbidity, and yet humans have a predilection for resting and copiously engaging in sedentary behaviors.

Figure 8 *Round One Cover Page*

Hello Delphi Bulldog Panelist.

I placed your email address in the "Bcc" address window to keep your identity confidential.

Note: Please reply to this email now to say, "Got it." That way I will know that you receive it.

Welcome to the Golden Bulldog Delphi Advisory Panel on Managing Lifelong Physical Activity and Resting Behavior. You are one of nine Golden Bulldog “experts” on this advisory panel. All panelists taught at Sir Winston Churchill High School (SWC). The average years of service of our panelists at SWC is 23. Every panelist taught in a different department. Thank you for joining our panel.

Your life experiences give you wisdom on living a healthy life, the knowledge that you may have lacked in earlier years. You are a graduate of the School of Hard Knocks. You did some things well in your lifetime and messed up other things. You taught for many years in one of Canada’s most progressive public schools. Your career, professional practice, intelligence, and life experiences render you a gift of wisdom in living life that is rare, valuable, and worth sharing.

A Delphi Method is a method for obtaining a “consensus” of wisdom and advice from a panel of “experts.” Anonymity is assured so that panel members will not feel inhibited in responding. Anonymity also inhibits the formation of a “herd response” to the questions.

I separated the first round and demographic questions to avoid overload in the first week.
There will be three rounds. I will distribute the demographic questionnaire separately.

I will distribute each of the three Round 1 questions in separate emails. Please return your response by replying to that email. That should make it easier to keep track of questions and replies.

I am happy with whatever response you give. They are open-ended questions about your entire life. I thought that would take at least 90 minutes.

But it is up to you to give as detailed or as brief responses as you wish.

Thanks much for your replies.

4.5.2 Queries

Three open-ended questions elicited panelist advice for their 15-year-old selves on living a healthful lifestyle by optimizing the benefits of physical activities and mitigating damage from sedentary behaviors. Panelists were given six days to respond to the following questions.

1. From your life experiences, what advice do you have for your 15-year-old self to optimize the right kind and amount of physical activity to arrive at your present age in the best possible health? Please explain in terms of your life experiences why you gave this advice.
2. From your life experiences, what advice do you have for your 15-year-old self to limit the wrong kind of resting behavior to arrive at your present age in the best possible health? Please explain in terms of your life experiences why you gave this advice.
3. From your life experiences, what advice do you have for your 15-year-old self to compromise (mix and match) physical activity and resting behavior to arrive at your present age in the best possible health? Please explain in terms of your life experiences why you gave this advice.

4.5.3 Analysis

The replies to the three open-ended queries by eight panelists and a biography by this study's first author were transcribed into 225 assertions, which were reduced to 115 summary assertions by combining assertions with similar content and eliminating redundancy. The 115 remaining assertions were manually grouped into 13 themes. All 115 assertions, grouped by theme, were advanced to Round 2.

4.5.4 Consensus Requirement to Advance an Assertion to Round 2

All 115 assertions, grouped by theme, as seen in Table 10, were advanced to Round 2.

Table 10 *All 115 Assertions Derived from Round 1 Were Used in Round 2 Voting*
✓ indicates that the assertion received 50%+ of the vote in Round 2 and was advanced to Round 3.

	#	Assertion
Theme 1: Avoid addictive substances.		
✓	1	Stay away from using drugs, alcohol and negative social behaviors to bolster perceived physical and mental well-being. It is hard to come out of the rabbit holes created by these behaviors.
✓	2	Avoid the use of alcohol and other drugs that impair and damage body parts when young. Find interactive social activities that do not use social drugs if possible.
✓	3	Be cautious even of pain medication.
✓	4	Limit the amount of screen time in your life. TV, computers, cell phones, tablets, and Xboxes can be addictive and potentially destructive.
✓	5	Addictions hijack your brain and enslave you to toxic chemicals and behaviors. Stay free. 100%
✓	6	Tobacco and excessive alcohol are enemies. Avoid!
✓	7	Smoking really does cause cancer, early dementia, lung disease, diabetes, and loss of sex appeal.
✓	8	Smoking takes up a lot of free/leisure time and drains energy.
✓	9	Drinking and eating and staying up all night is not restful, not a healthy balance.
✓	10	Strike a balance and don't drink too much. Do something active with friends, then have a couple beers.
✓	11	Drink less, in moderation. Being more active results in less partying.
✓	12	Watching sports on tv can be fun but don't make it a consuming passion. Play is more productive.
Theme 2: Avoid injuries when young.		
✓	13	Take care of injuries to avoid harmful later life effects.
✓	14	If injured - learn to rehab, not reinjure. You might think that you are healed after an injury, but later, it comes back to haunt you.
✓	15	Your body will tell you when it needs rest. Listen to it.
✓	16	See your doctor sooner rather than later. Waiting exacerbates injuries and ailments.
x	17	Being physically active can have hurtful aftereffects of injury and wear. Do not regret that cost.
✓	18	Be competitive and focused to achieve what you want in your sports career but beware that those injuries become a hinderance to living a pain free, fully functional senior's existence.
✓	19	Participate in strenuous activities when young that do not result in physical damage to your body. Injuries acquired when young tend to flare up when older.
✓	20	Pursue low-impact activities that you enjoy. Engage in walking, XC skiing, and cycling. These activities will result in prolonging exercise well into your senior years. Many older adults have knee and hip problems, making movement difficult.
✓	21	Severely ruptured tendons cannot always be repaired. Some injuries last a lifetime. Be cautious.

Table 10 *All 115 Assertions Derived from Round 1 Were Used in Round 2 Voting*
✓ indicates that the assertion received 50%+ of the vote in Round 2 and was advanced to Round 3.

	#	Assertion
Theme 3: Lead a balanced life.		
✓	22	Find the right balance between activity and rest.
✓	23	Be a serial hobbyist. Be good but not brilliant at a lot of things.
✓	24	Build in daily time for reflection and positive self-assessment.
✓	25	Your goal is not to win, but to endure.
✓	26	Learn to shut things off, turn down the adrenaline, and let the body recover. When overbooked - say no.
✓	27	Work towards a balanced lifestyle that involves coordinating work and duty requirements with recreational, physical, mental, and emotional support activities and choosing friends who support that lifestyle and belief.
✓	28	Devote time daily to your physical body and mind and your body will benefit when older. Once you finish your competitive sports, continue to exercise in a regular regime that includes a balance of aerobic, team sport, and muscle strengthen activities so you can have functional fitness all of your life.
x	29	Intense cardio activity increases dopamine, serotonin, norepinephrine, epinephrine, endocannabinoids, and endogenous opioid peptides in the brain. Your stress becomes manageable, and you will be stone sober in the morning.
✓	30	Be aware of your physical conditions such as weight or dependence on social avoidance and seek help and advice to optimize your physical and mental health.
✓	31	Do not pursue a career that does not satisfy your mental health, self-perception or physical needs.
✓	32	Walk, hike, golf, kayak, paddleboard, bike, swim, cross-country ski, do Qigong, yoga and weights. Build Lego projects, do adult paint-by-number, read and play games on a tablet, watch TV, and learn to speak Spanish.
✓	33	Playing guitar, learning new instruments and drawing may come at the expense of sleep, but it can give extreme satisfaction and wonderful life experiences and opportunities.
Theme 4: Make activity routine.		
✓	34	Develop habits when young and physical activity becomes part of who you are. Don't limit yourself.
✓	35	You have only one body. Look after it. Regular exercise keeps the parts tuned and lubricated.
✓	36	Make exercise routine and avoid excuses for not doing it. It is harder to get back into a good exercise regime when not exercising consistently.
✓	37	Schedule activity every day to exercise your heart and lungs (cardio), maintain muscle tone, and stimulate your mind. Your body will come to crave it. You will experience stress relief.
✓	38	Learn to enjoy activities such as cycling, gardening, snow shoveling, cleaning the house.
✓	39	If tired - have a nap - and continue, as much as possible, a regular sleep time.

Table 10 *All 115 Assertions Derived from Round 1 Were Used in Round 2 Voting*
✓ indicates that the assertion received 50%+ of the vote in Round 2 and was advanced to Round 3.

	#	Assertion
Theme 5: Educate your body.		
✓	40	Your body isn't a temple (old saying), but rather the vehicle to get to the temple! You need to understand your body and what is suitable for it.
✓	41	Balance exercise between high intensity and moderate training to avoid harmful wear and tear.
✓	42	The biggest mistake is not trying or participating. Do it. Don't live to regret not doing it.
x	43	Compete at every sport, but learn to cope, accept losses, and improve oneself. Victory seldom teaches anything.
✓	44	Seek balance in stretching, strength training, mental health benefits, and medical health care to keep your body in the best physical condition possible.
x	45	Cardio and strength training makes everything else easier.
✓	46	During early weight training avoid maximum weight with maximum repetition sessions and concentrate on an overall balanced program.
x	47	Skill acquisition occurs with thousands of repetitions. Do repetitions at the highest speed possible and avoid comfort.
x	48	Learn yoga's child pose, cat pose, and cow pose. Use to relax.
x	49	Learn to rehabilitate
Theme 6: Enjoy physical activity.		
✓	50	Much of physical activity/sport/recreation is based on participation. Remember to savor the lessons learned, friendships made, joys from competing, and the physical benefits you gain from preparation, which filter through all aspects of life!
✓	51	Find physical activities that are fun and/or challenging to do either by yourself, or better at times, with friends. That will make it easier to just do it and thus reap the rewards.
✓	52	Everyone needs physical activities they enjoy or they're not likely to keep them up. They may be physical, but they can also be totally "restful" and restorative in terms of one's mental well-being.
x	53	Words matter. It's not a workout. It's playtime!
✓	54	Choose activities that are fun - they will be self-motivating.
✓	55	Do exercise that is enjoyable and not a chore.
✓	56	Pair exercise with what you enjoy: music, podcasts, streaming exotic workouts.
✓	57	There are hurdles and challenges to face, but anticipation (ie dread/fear) is probably more harmful.
✓	58	Listen to your body. You'll likely be involved in different physical activities as you age. Enjoy them.
✓	59	If you don't use your body, then you've missed out on a lot!

Table 10 *All 115 Assertions Derived from Round 1 Were Used in Round 2 Voting*
✓ indicates that the assertion received 50%+ of the vote in Round 2 and was advanced to Round 3.

	#	Assertion
		Theme 7: Seek companionship and sharing.
✓	60	Play a pickup game, community sports, school teams whenever others are available: baseball, basketball, soccer ball, football. A couple of hats or jackets make good goalposts.
x	61	Golf is a true life sport for competition and socializing. It is successful and satisfying.
✓	62	An active and engaged mind is as important as being physically active. Find social situations to share these activities with and present a good example to your children regarding staying active.
✓	63	Find mental and physical well-being in positive social interaction and giving and volunteering.
✓	64	Spend time working and involving yourself in worthwhile endeavors that benefit others and those around you. Coaching and refereeing can be extremely satisfying.
✓	65	Take up social interaction activities that involve physical movement, e.g., dancing, hiking clubs, biking with the family.
✓	66	Some families expect everyone to work to get ahead and may not be aware of extracurricular school activities. Educate your parents.
		Theme 8: Travel and move in the wilderness.
✓	67	Get into outdoor pursuits like hiking, snowshoeing, skiing, climbing, skating, and tobogganing when young. This type of exercise can be done alone or in small groups for your whole life without the logistics and hassle that team sports require.
x	68	Live in a beautiful place surrounded by stunning mountains and mysterious forests and soulful serene lakes. Being outside can be a spiritual experience.
x	69	Where possible, live and work near an urban park and visit it often.
x	70	Join a club, hostel, or meetup for outdoor pursuits, particularly in the mountains.
x	71	Cultivate lifelong friends and a love for the wilderness. Join a Venturer Scout Company (ages 15-17), Rover Scout Crew (ages 18-26), or Calgary Rowing Club (Juniors aged 10-18, Seniors aged ≥ 19).
x	72	Hike and camp in Kananaskis Country and canoe the Red Deer River.
✓	73	Make travel a passion and a hobby.
✓	74	Camp, hike and walk your vacations. That's when you hear, taste, smell, and feel the culture.
x	75	Backpack through Western Europe for at least two months before beginning your career.
x	76	Travel to warmer climes where daily walking is feasible.
✓	77	While vacationing build in time for walking, running, etc. and limit your time sitting around the pool.

Table 10 *All 115 Assertions Derived from Round 1 Were Used in Round 2 Voting*
✓ indicates that the assertion received 50%+ of the vote in Round 2 and was advanced to Round 3.

	#	Assertion
		Theme 9: Move instead of resting.
x	78	Don't hide when eating chocolate bars. Read in the living room when parents or siblings are around.
x	79	Omitted as this was a duplicate assertion.
✓	80	Don't restrict outdoor physical activities due to weather conditions.
✓	81	Skip lunch & afternoon brain fog. Go for a run or walk, preferably with colleagues and friends.
✓	82	Don't be lazy. Mow the lawn and shovel your walk yourself.
✓	83	Find hobbies that involve movement and mental stimulation.
x	84	Carry a trash bag. When you see litter, bend your waist, and pick it up.
x	85	Put a swing in your yard. Swing instead of sitting.
✓	86	Get 7-9 hours of continuous sleep daily – avoid napping too often.
		Theme 10: Go it alone.
✓	87	Team sports are fine but enjoy them as a social experience - in a few years with career and family you will probably end up playing less and less on the "company slow pitch team" and then none at all. Individual pursuits like hiking last a lifetime.
✓	88	Develop some individual sports activities like cross country skiing and golf.
✓	89	Pursue more individual activities. Team sports were a means to quickly meet & make new friends in high school, but when high school ends, it is difficult to get on a basketball or volleyball team for young women.
✓	90	Concentrate on lifelong activities that reduce competition and stress participation.
		Theme 11: Invest in technology and wearables.
x	91	Buy "smart" equipment and wearables that interacts with streaming workouts and services.
x	92	A family that can afford a fridge can afford gym equipment.
x	93	Be aware of how much sleep you get and how much active movement per day – modern technology helps you in this, like Fitbit, smart phone & watch apps.
x	94	Personalize your exercise. Buy a fitness watch that measures heartbeat, oxygen, power, pace, etc. when working out.
x	95	Wear an Apple watch. You can program your daily exercise / routine / goals into it. The watch continually reminds you of these goals throughout the day. As you begin to reach your goals easily, you can reprogram to make your goals more difficult.
x	96	Buy the best exercise clothing you can afford. The best lasts for years and you have maximum comfort that whole time.
x	97	If standing at a desk for extended periods, consider an under desk treadmill.
✓	98	If working at a desk for extended periods, consider standing part of the time. Needs height adjustable desk.
x	99	Install a chin-up bar in an open doorway of your home and use it frequently.

Table 10 *All 115 Assertions Derived from Round 1 Were Used in Round 2 Voting*
✓ indicates that the assertion received 50%+ of the vote in Round 2 and was advanced to Round 3.

	#	Assertion
		Theme 12: Be selective in friendships.
x	100	Choose friends that are activity oriented. They help motivate and get you out to do activities.
✓	101	Be wary about friendships that are not interested in physical activity.
✓	102	Choose wisely - try to hang out with those who inspire you and encourage you to stay active and not waste too much time vegging out.
✓	103	Choosing healthy activities and limiting negative ones can be aided or discouraged by the friends one chooses.
x	104	Seek mentors that stress the importance of staying active and physically fit for life with sports and activity and that diminish competition.
✓	105	Encourage the participation of family and friends in your physical activities.
✓	106	Avoid short cuts. Build positive relationships with colleagues, friends and family. See more than one way out of conflicts.
		Theme 13: Manage internet technology.
✓	107	Limit the time that you watch TV, read books, oversleep, play computer games, visiting social media, sit doing nothing, or hanging out with friends doing not much of anything and other activities that don't involve moving.
✓	108	Use your computer as a tool to find things out and how to do things.
✓	109	Never ride when you can walk. Never drive when you can cycle. Never cruise when you can row.
✓	110	Play team sports or go for a walk with someone instead of long conversations on the phone.
✓	111	Silence notifications. Phones and watches are tools. Texts and emails do not disappear.
✓	112	When sitting at a desk, habitually go for a stroll for ten minutes each hour, every hour!
✓	113	Seek careers and jobs that keep you active daily.
x	114	Schedule business meetings outside when discussion is the main objective.
x	115	Park your car far away from entrances to any mall or building; the further away the better.

4.6 Round 2

4.6.1 Email Cover Page

The cover email reminded panelists that they were advising their 15-year-old selves on optimizing PA and mediating SB for healthful living for life.

4.6.2 Queries

Panelists were asked to rate each of the 115 assertions derived from their collective responses in Round 1 (see Table 10). Panelists rated each assertion by selecting one of five responses from a dropdown menu: *Critically Important, Important, Moderately Important, Not Important, and Irrelevant* (see Table 11).

Panelists progressed through the questionnaire one theme at a time, paced by a progress bar at the bottom of the screen. Panelists were not allowed to skip a question. Upon submitting their responses, Google Forms automatically sent a copy of the responses to the panelist.

4.6.3 Analysis

A frequency distribution table for the 115 assertions was used to record the assertion response frequencies and percentages. A cumulative percentage of the sum of "*Critically Important*" and "*Important*" was used to select assertions for advancement to Round 3 (Table 11).

Table 11 ***Example of Frequency Table***

This is an example of a statement advising physical activity to promote healthful living.			
	Frequency	**Percent**	**Cumulative Percent**
Critically Important	1	11.1	11.1
Important	1	11.1	22.2
Moderately Important	3	33.3	55.6
Not Important	2	22.2	77.8
Irrelevant	2	22.2	100.0

4.6.4 Consensus Requirement to Advance an Assertion to Round 3

A consensus requirement of greater than 50% of the cumulative percentage of "Critically Important" and "Important" selected responses was selected to advance an assertion to Round 3. Eighty-two of the 115 assertions met this consensus requirement and were advanced to Round 3 for consideration.

4.7 Round 3

4.7.1 Email Cover Page

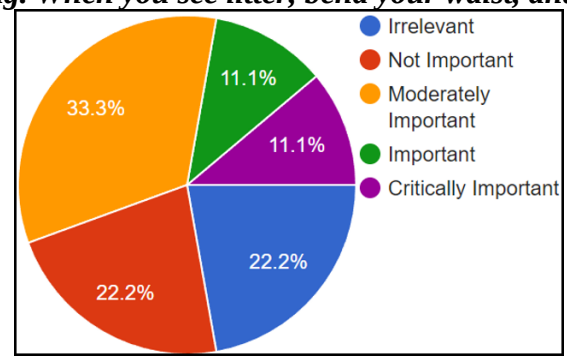
In Round 3, the email cover page repeated the queries and results of Rounds 1 and 2. Panelists were reminded that their task was to advise their 15-year-old selves on how to achieve optimal health through management of their PA and mitigation of SB.

4.7.2 Queries

Results for the 82 assertions from Round 2 were presented as pie charts showing the Round 2 percentage of panelists who selected each option for each assertion. (See Figure 9 for an example.) Panelists made a binary selection for each assertion to "Advise" or "Don't Advise" their 15-year-old-selves to optimize PA and mitigate SB.

Figure 9 *Example of a Round Three Assertion and Corresponding Pie Chart*

Carry a trash bag. When you see litter, bend your waist, and pick it up.



4.7.3 Analysis

Twenty-six assertions were unanimously recommended by the panel to advise to adolescents (see Table 12). Thirty-three assertions not unanimously recommended were recommended by 78% - 89% of the panel (Table 13). This total of 59 assertions were grouped by eleven remaining themes of the panel's recommendations to their 15-year-old selves on optimizing PA and mediating SB for healthful living for life. The eleven themes were prioritized by combining the twenty-six unanimous assertions and thirty-three assertions (see Table 14).

Table 12 *Unanimous Assertions Receiving **100%** in Round 3 Voting.*

#	Assertion
	Theme 1: Avoid addictive substances.
1.	Avoid the use of alcohol and other drugs that impair and damage body parts when young. Find interactive social activities that do not use social drugs if possible.
2.	Limit the amount of screen time in your life. TV, computers, cell phones, tablets, and Xboxes can be addictive and potentially destructive.
3.	Addictions hijack your brain and enslave you to toxic chemicals and behaviors. Stay free.
4.	Tobacco and excessive alcohol are enemies. Avoid!
	Theme 2: Avoid injuries when young.
5.	If injured - learn to rehab, not reinjure. You might think that you are healed after an injury, but later, it comes back to haunt you.
6.	Your body will tell you when it needs rest. Listen to it.
7.	Pursue low-impact activities that you enjoy. Engage in walking, XC skiing, and cycling. These activities will result in prolonging exercise well into your senior years. Many older adults have knee and hip problems, making movement difficult.
	Theme 3: Lead a balanced life.
8.	Find the right balance between activity and rest.
9.	Learn to shut things off, turn down the adrenaline, and let the body recover. When overbooked - say no.
10.	Work towards a balanced lifestyle that involves coordinating work and duty requirements with recreational, physical, mental, and emotional support activities and choosing friends who support that lifestyle and belief.
	Theme 4: Make activity routine.
11.	Develop habits when young and physical activity becomes part of who you are. Don't limit yourself.
12.	You have only one body. Look after it. Regular exercise keeps the parts tuned and lubricated.
13.	Make exercise routine and avoid excuses for not doing it. It is harder to get back into a good exercise regime when not exercising consistently.
14.	Schedule activity every day to exercise your heart and lungs (cardio), maintain muscle tone, and stimulate your mind. Your body will come to crave it. You will experience stress relief.
	Theme 5: Educate your body.
15.	Your body isn't a temple (old saying), but rather the vehicle to get to the temple! You need to understand your body and what is suitable for it.
16.	The biggest mistake is not trying or participating. Do it. Don't live to regret not doing it.
17.	Seek balance in stretching, strength training, mental health benefits, and medical health care to keep your body in the best physical condition possible.

Table 12 *Unanimous Assertions Receiving **100%** in Round 3 Voting.*

#	Assertion
Theme 6: Enjoy physical activity.	
18.	Much of physical activity/sport/recreation is based on participation. Remember to savor the lessons learned, friendships made, joys from competing, and the physical benefits you gain from preparation, which filter through all aspects of life!
19.	Listen to your body. You'll likely be involved in different physical activities as you age. Enjoy them.
Theme 7: Seek companionship and sharing.	
20.	An active and engaged mind is as important as being physically active. Find social situations to share these activities with and present a good example to your children regarding staying active.
21.	Find mental and physical well-being in positive social interaction and giving and volunteering.
22.	Take up social interaction activities that involve physical movement, e.g., dancing, hiking clubs, biking with the family.
Theme 8: Travel and move in the wilderness.	
23.	Get into outdoor pursuits like hiking, snowshoeing, skiing, climbing, skating, and tobogganing when young. This type of exercise can be done alone or in small groups for your whole life without the logistics and hassle that team sports require.
24.	Make travel a passion and a hobby.
Theme 9: Move instead of resting.	
25.	Find hobbies that involve movement and mental stimulation.
Theme 10: Go it alone.	
26.	Develop some individual sports activities like cross country skiing and golf.
Theme 11: Invest in technology and wearables.	
	No unanimous assertion was recorded for Theme 11.
Theme 12: Be selective in friendships.	
	No unanimous assertion was recorded for Theme 12.
Theme 13: Manage internet technology.	
	No unanimous assertion was recorded for Theme 13.

Table 13 *Assertions receiving **78% - 89%** in Round 3 Voting*

#	Assertion

Table 13 *Assertions receiving **78% - 89%** in Round 3 Voting*

Theme 1: Avoid addictive substances.

1. Stay away from using drugs, alcohol, and negative social behaviors to bolster perceived physical and mental well-being. It is hard to come out of the rabbit holes created by these behaviors.
2. Be cautious even with pain medication.
3. Smoking really does cause cancer, early dementia, lung disease, diabetes, and loss of sex appeal.
4. Smoking takes up a lot of free/leisure time and drains energy.
5. Drinking and eating and staying up all night is not restful and not a healthy balance.
6. Strike a balance. Don't drink too much. Do something active with friends, then have a couple of beers.
7. Drink less in moderation. Being more active results in less partying.
8. Watching sports on tv can be fun but don't make it a consuming passion. Play is more productive.

Theme 2: Avoid injuries when young.

9. Take care of injuries to avoid harmful later life effects.
10. See your doctor sooner rather than later. Waiting exacerbates injuries and ailments.
11. Be competitive and focused on achieving what you want in your sports career but beware that those injuries will become a hindrance to living a pain-free, fully functional senior existence.
12. Participate in strenuous activities when young that do not result in physical damage to your body. Injuries acquired when young tend to flare up when older.

Theme 3: Lead a balanced life.

13. Devote time daily to your physical body and mind, and your body will benefit when you get older. Once you finish your competitive sports, continue to exercise in a regular regime that includes a balance of aerobic, team sport, and muscle-strengthening activities to have functional fitness all of your life.
14. Be aware of your physical conditions, such as weight or dependence on social avoidance, and seek help and advice to optimize your physical and mental health.
15. Do not pursue a career that does not satisfy your mental health, self-perception, or physical needs.
16. Seek careers and jobs that keep you active daily.

Theme 4: Make activity routine.

17. Learn to enjoy cycling, gardening, snow shoveling, and cleaning the house.

#	Assertion

Theme 5: Educate your body.

Table 13 *Assertions receiving **78% - 89%** in Round 3 Voting*

18. Balance exercise between high intensity and moderate training to avoid harmful wear & tear.

Theme 6: Enjoy physical activity.

19. Find physical activities that are fun and challenging to do either by yourself or, better at times, with friends. That will make it easier to just do it and thus reap the rewards.
20. Everyone needs physical activities they enjoy, or they're not likely to keep them up. They may be physical, but they can also be totally "restful" and restorative in mental well-being.
21. Choose activities that are fun - they will be self-motivating.
22. Do exercise that is enjoyable and not a chore.
23. If you don't use your body, you've missed out on a lot.

Theme 7: Seek companionship and sharing.

24. Play a pickup game, community sports, or school teams whenever others are available: baseball, basketball, soccer ball, football. A couple of hats or jackets make good goalposts.
25. Spend time working and involving yourself in worthwhile endeavors that benefit others and those around you. Coaching and refereeing can be extremely satisfying.

Theme 8: Travel and move in the wilderness

26. While vacationing, build in time for walking and hiking, and limit your time sitting around the pool.

Theme 9: Move instead of resting.

27. Don't be lazy. Mow the lawn and shovel your walk yourself.
28. Get 7-9 hours of continuous sleep daily – avoid napping too often.

Theme 10: Go it alone.

29. Concentrate on lifelong activities that reduce competition and stress participation.

Theme 11: Be selective in friendships.

30. Choose wisely - try to hang out with those who inspire you and encourage you to stay active and not waste too much time vegging out.
31. Choosing healthy activities and limiting negative ones can be aided or discouraged by friends.
32. Encourage the participation of family and friends in your physical activities.
33. Avoid shortcuts. Build positive relationships with colleagues, friends, and family. See more than one way out of conflicts.

Table 14 *Panel's Prioritized Advice to Adolescents by Theme*

#	Recommendations	100%	78%-89%
Theme 1: Avoid addictive substances.			
	Addictions hijack your brain and enslave you to toxic chemicals and behaviors. Avoid alcohol, tobacco, and other addictive substances. Beware of digital addiction of too much screen time.	4	8

Table 14 *Panel's Prioritized Advice to Adolescents by Theme*

#	Recommendations	100%	78%-89%
Theme 2: Avoid injuries when young.			
	Listen to your body when it tells you to rest. When injured, rehab, don't reinjure. Participate in strenuous activities that do not physically damage your body, such as walking, cross country skiing, and cycling.	3	4
Theme 3: Lead a balanced life.			
	Coordinate work and duty requirements with recreational, physical, mental, and emotional support activities. Choose friends that support an active lifestyle and healthy beliefs. Beware of careers that do not satisfy both mental and physical needs.	3	4
Theme 4: Make activity routine.			
	Make exercise routine. Develop habits that make physical activity part of who you are. Beware excuses for not exercising.	4	1
Theme 5: Educate your body.			
	Understand your body and what is suitable for it. Balance exercise between high intensity and moderate training.	4	1
Theme 6: Enjoy physical activity.			
	Listen to your body. Savor the lessons learned, friendships made, joys from competing, and the physical benefits gained from the preparation that filter through all aspects of life. Choose activities that are fun and not a chore.	2	5
Theme 7: Seek companionship and sharing.			
	Seek social situations that involve physical activity such as dancing, hiking clubs, biking with family, pickup games, and team sports like baseball, basketball, and soccer. Involve yourself in worthwhile endeavors that benefit others, such as coaching and referring.	3	2
Theme 8: Travel and move in the wilderness.			
	Make travel a passion and a hobby. Get into outdoor pursuits like hiking, snowshoeing, skiing, climbing, skating, and tobogganing when young. Plan vacation time for walking and hiking.	2	1
Theme 9: Move instead of resting.			
	Find hobbies that involve movement and mental stimulation. Avoid being lazy: mow the lawnmower and shovel the walk yourself.	1	2

Table 14 *Panel's Prioritized Advice to Adolescents by Theme*

#	Recommendations	100%	78%-89%
Theme 10: Go it alone.			
	Develop individual sports activities like cross-country skiing and golf. Concentrate on lifelong activities that reduce competition and stress participation.	1	1
Theme 11: Be selective in friendships.			
	Choose friends wisely. Hang out with those who inspire and encourage you to stay active and not waste time vegging out. Participate in physical activities with family and friends.	0	4

4.8 Discussion

To our knowledge, this is the first attempt to use a Delphi Method to formally tap the cumulative knowledge and wisdom garnered retrospectively from a lifetime of personal experiences and professional engagements of expert panelists. Wisdom is associated with, although not assured, by experiences over time (Parisi et al., 2009). This study tapped the knowledge and wisdom of twenty-first-century retired educators concerning advice to adolescents on living a progressive healthful lifestyle.

Drawing upon more than a half-century of life experience spanning the duration between the chronological ages of the panelists and their 15-year-old adolescent selves, this study documents lessons learned from a progression of life-altering choices and practices concerning physical and sedentary activities and panelists' perceptions of consequences.

The panel observed that youthful exposure to toxic substances, violent sports, abusive relationships, and indolent vocations was associated with diminished PA and increased sedentary practices throughout the lifecourse, culminating in compromised health, dysfunctionality, and annoyances in later life. Conversely, the panel noted that routine and balanced involvement with non-contact sports and activities, physically active companions, and active vocations increase the

likelihood of embodied health, functionality, and happiness in later years. The panel observed that physically educating the body and education about the body, having fun, traveling, and engaging in wilderness pursuits increased healthful practices and that young people today spend too much time on digital devices not available to the panelists' 15-year-old selves, foregoing activity, and sports that contribute to fitness and health.

Panelists were professionals who daily interacted as professional educators with adolescents for 3-4 decades. Drawing upon their own lifecourse experiences and their professional daily observations of adolescents, the panelists generated their advice.

This study incorporated two tiers of consensus, unanimity of 100% and a 78% - 89%, to prioritize 11 themes by importance. Uppermost among the recommendations is addiction avoidance and moderation of both substances such as tobacco and of behavior such as screen time. Panelists' advice distinguished absolute avoidance of tobacco from moderate consumption of alcohol and screen time. Recommendations for addiction avoidance hinted that balance was important. Leading a balanced life is the second most important advisory theme, emphasizing balancing physical, mental, and emotional practices. Panelists advised balancing work and recreation and career and sports.

Panelists aged ≥ 65 years attributed a high priority to injury avoidance when younger. These seniors witnessed a progression of ramifications of injuries over a lifecourse, beginning with experiences less appreciated in the earlier years of adolescence. Specific advice favored low-impact activities such as walking, cross-country skiing, cycling, and golf which are less likely to damage the body physically. There was a conspicuous absence of support in all assertions for high-impact activities such as football, boxing, hockey, and martial arts. Several assertions cautioned that early life injuries continue to impair later lifestyles.

4.9 Limitations

Several limitations were present in this study. First, all panelists taught in the same school, albeit in different departments and at different though overlapping years. A school attracts teachers favorable to the school's culture and repels teachers unfavorable to the school's culture. This implicit cultural bias possibly narrows the scope of life experiences and views available to the panel. Second, panelists who agreed to participate in the study may have different lifecourse experiences and opinions than those who did not accept our invitation. Third, anonymity, a prerequisite feature of the Delphi Method, removes nuanced communication experienced with face-to-face interaction, possibly decreasing consensus. Fourth, the panelists had middle-class educations and careers, availing enrichment opportunities less accessible to those less financially fortunate. Fifthly, panelists advised their 15-year-old selves, adolescents living half a century ago. Opportunities and challenges for contemporary adolescents may differ.

4.10 Future Directions

Adolescents may benefit from implementing the advice from this Delphi project. The panel delivered sage advice, but "the devil is in the details." Generic advice must be implemented with workable strategies and tactics. It is not enough to know what must be done but also how to implement the advice. Adolescents need to learn successful life strategies and tactics to avoid addiction, establish exercise routines, recognize when an injury should be examined by a medical practitioner, and be assertive in distancing themselves from acquaintances with incompatible values and lifestyles. Balancing time for academic and career pursuits with engagement in physical activities requires direction. Adolescents need explicit exemplars of how to substitute PA for sedentary habits.

Panelists in this survey drew upon decades of experiences and professional interaction with and observations of adolescents. Future surveys should compare the relative contributions of personal experiences and professional observations with the synergistic contribution from the combination of the two sources versus a summative contribution of the different recommendations based on personal lifecourse experiences versus professional observations of adolescents.

This study's assertions have direct implications for parental and school policies. The findings of this study suggest prioritizing research to answer pragmatic questions of high import to health. Should risk-averse sports (basketball, badminton) be prioritized over injury-prone sports (boxing, football)? Should there be increased vigilance and support for alternative stimulation to addictive substances and practices? Should youth be counseled on what to seek in constructive friendships and how to be constructive friends? What practices best support making healthy lifestyle choices such as regular physical activities? How does research inform us about the relative impact of moderate and high-intensity exercise? What community and other resources exist for shared experiences of physical activities for dancing, hiking, cycling, and team sports? What are affordable strategies for accessing outdoor physical activities, such as established youth groups? Should we cultivate norms and expectations that older adults and not just younger adults cut grass and shovel walks? When we don’t find ourselves with companions, what opportunities exist in our communities for physical activities such as day hikes, strolling shopping malls, wandering, and cycling park pathways?

4.11 Conclusion

Healthful living requires the appropriate management of many factors, such as nutrition, sleep, and stress. This study elicited advice from older adults for adolescents on living a healthful

lifestyle by optimizing the benefits of physical activities and mitigating damage from sedentary behaviors over their lifecourses. The panel of this Delphi project offered a plethora of sound advice to adolescents on how to mix and optimize the right kind and amount of PA and how to limit SB to arrive half a century later in better health. Avoid Addiction. Lead a balanced life. Avoid injuries. Educate your body. Make PA routine. Seek companionship and share experiences, but it's okay to do it alone. Do what you enjoy. Travel and experience the wilderness. It's okay to watch TV, but it's better to play.

4.12 Acknowledgments

The authors thank the panelists for answering all the queries and providing insightful responses drawn from their personal and professional lifecourses of experience and reflection.

4.13 Declaration of Conflicting Interests

The first author, Gerald Donaldson, was one of the nine panelists. The authors otherwise declare no potential conflicts of interest with respect to the research, authorship, and publication of this article.

4.14 Funding

The authors received no financial support for this article's research, authorship, or publication.

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Chapter Five: Conclusions & Future Directions

In a race, continue running full steam through the finish line.

- Advice every running coach should give their athletes.

Now, this is not the end.

It is not even the beginning of the end.

But it is, perhaps, the end of the beginning.

Sir Winston Churchill —Lord Mayor's Luncheon, Mansion House
following the victory at El Alamein, North Africa,
London, 10 November 1942.

5.1 Summary

5.1.1 Physical Literacy Defined

The scope of the Physical Literacy (PL) paradigm is comprehensive. "As appropriate to each individual, physical literacy can be described as the *motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engaging in physical activities for life"* (Whitehead, 2019a, p. 8, emphasis in original). Physical literacy is not a state to be reached but rather a journey for life unique to each individual (Taplin, 2019; Whitehead, 2013).

5.1.2 Synopsis

This dissertation sought to provide novel and significant contributions to the physical literacy literature through triangulation of mixed methods. In chapter two, theoretical arguments based on a twenty-first-century science perspective were used to support the philosophical underpinnings of Margaret Whitehead's physical literacy paradigm. In chapter three, the motivation component of physical literacy was explored with a quantitative study of randomized comparative trials to find that adults aged ≥ 65 enjoyed cycling more when exergaming and enjoyed exergaming while cycling equally with a monitor or VR headset interface. In chapter four, the provision that physical literacy is practiced for life was informed with a mixed methods Delphi project that enabled the expert collaboration of nine panelists aged ≥ 65 to generate eleven recommendations to manage physical activities and mitigate sedentary behaviors before age 65 to optimize healthspan.

5.2 Physical Literacy Vindicated

5.2.1 Findings

In chapter two, research exploring *Physical Literacy Vindicated: The Mind Is the Function of a Body Embedded Brain* (Donaldson, Sheehan, et al., 2022b) was discussed. The merits of Whitehead's perspective were discussed from both a philosophical and a scientific perspective. We argued that modern science complemented existentialism and phenomenology in justifying and explicating the importance of physical activity and physical literacy for human beings. Science research in the twenty-first century demonstrated that the mind is an embodied process of a brain within a body, interacting with its environment (Johnson & Tucker, 2021). "A significant challenge in establishing the concept of physical literacy is to help people understand the role of the lived embodiment and show how this supports a monist view of a human being" (Whitehead, 2010b, p. 23). We documented how our species evolved the ability and need for persistent movement to survive (Karnazes, 2006; Liebenberg, 2006, 2008; Raichlen & Alexander, 2020).

Other studies have examined the underpinnings of PL from a philosophical perspective (Pot et al., 2018; Shearer et al., 2018; Whitehead, 2010c, 2019b). To our knowledge, this is the first conceptualization of the underpinnings of Whitehead's PL paradigm from a scientific perspective (Edwards et al., 2017).

5.3 Enjoyment of Interactive Cycling While Exergaming

5.3.1 Findings

In chapter three, research exploring *Adult Enjoyment, Perceived Effort, and Actual Effort While Riding Interactive Stationary Bikes in Different Virtual Levels of Chase-Based Exergaming Interfaces* (Donaldson, Sheehan, Boyd, et al., 2022, submitted for publication) was

discussed. This experimental, randomized, comparative trial was used to examine the impact of Enjoyment, Perceived Effort, and Actual Effort among a sample of 42 adults ≥ 65 (N=22 males, N=20 females). Participants first rode interactive exergaming stationary cycles while playing exergames without an extended reality interface and then with either a 2D Monitor or a 360° virtual reality headset. Two-way Mixed ANOVAs were used to analyze Enjoyment, Perceived Effort, and Actual Effort on Gaming (without exergaming and with exergaming) and Interface (Monitor and Headset). Results showed that Enjoyment and Perceived Effort – but not Actual Effort – was significantly greater while riding a stationary cycle when engaged in exergaming than when not engaged in exergaming. Enjoyment and Perceived Effort were similar for both interface types (Monitor or Headset).

Chapter 3 reported that for adults aged ≥ 65, exergaming while riding an interactive stationary bike was more enjoyable than riding without exergaming, a finding supported by earlier studies that found that exergaming increases the enjoyment of PA engagement (Evans et al., 2021; Farrow et al., 2019; Monedero et al., 2015). Exergaming while cycling was important to enjoyment with both a 2D monitor or a 360º VR headset, suggesting that it was the exergaming and not the type of interface that induced increased enjoyment.

Perceived Effort was higher when riding with exergaming than when riding without exergaming, regardless of the interface type, possibly due to the increased cognitive load of gaming over not gaming. This finding differs from a pilot study (Gao et al., 2017), which reported that perceived effort was lower when participants rode a VR-based VirZOOM bike versus a traditional stationary exercise bike.

5.3.2 Future Directions

Exergaming with 2D monitor or television interfaces for adults aged ≥ 65 may be an effective tool to motivate PA engagement without requiring additional purchases of VR headsets. Research is needed to test whether exergaming is more important than the type of interface for inducing motivation by enjoyment. Future studies should use the same exergames to eliminate confounding results when two games have different strategic features.

Research is needed to compare the enjoyment of adults aged ≥ 65 while exergaming with and without other immersive interactive technologies such as 2D monitors, 360° VR headsets, AR eyeglasses, and interactive game-playing robots. Enhanced enjoyment may accrue from bodily movement while exergaming and not exclusively from the sensory imagery of the exergames.

Research is needed to compare enjoyment with animated interactive exergaming equipment against enjoyment with human trainers while using interactive "smart" exercise equipment such as those marketed by Peloton Interactive (2021) and NordicTrack (iFIT Health & Fitness Inc., 2021) further to enhance our understanding of different human learning environments. Similarly, it would be informative to examine the enjoyment motivation of streaming workouts from remote locations as streamed by iFIT Health & Fitness Inc. (2021) compared to streaming studio workouts as streamed by Apple Fitness+ (Apple Inc., 2021).

Future studies should compare different interfaces using the same bike model and identical exergames programmed for the other interfaces. Alternatively, in future studies, all participants could repeat the same trial on the second day, meaning they would ride the bike they did not ride and play the exergame they did not play on the first day. There would be a learning

history effect, but this would allow statistical comparison of measures to tease out the impact of the differences in the two models of bikes and variations of play in the games.

5.3.3 Future Directions

Margaret Whitehead's PL paradigm lies in the holistic assumption that the biology and functionality of the human body are intimately interconnected, that no organ functions autonomously, and that every organ, including the brain, and perhaps, especially the brain, impacts and is likewise impacted by other bodily biology. Research is needed to explore neurological and physiological interconnections between the brain and other organs of the body, including the central nervous system.

We empathized with Whitehead's despair that "the importance of movement development in early childhood was being forgotten. The focus…was directed principally towards the development of language, numeracy, and social skills" (Whitehead, 2010a, p. 3). Research is needed to investigate how physical activity engagement can be used to advance and enhance thinking skills and knowledge retention. Education will benefit by integrating physical movement activities with traditional cognitive learning objectives. Research is needed that compares learning outcomes: (a) between conventional seated classroom pedagogies and listening to podcasts and audiobooks and conversing while hiking wilderness trails, (b) between viewing documentaries while students sit idly in rows in traditional classrooms and viewing the same documentaries while walking and running on treadmills and ellipticals, cycling on stationary cycles, and rowing on stationary rowing machines, and (c) leveraging the metaphorical correspondences between bodily movements and cognitive concepts akin to the Seymour Papert (1980) turtle robotics simulation and logo programming language as students.

5.4 Managing Physical & Sedentary Behaviors for Life

5.4.1 Findings

In chapter four, research exploring *Optimize Physical Activity & Mitigate Sedentary Behavior for Life: An Electronic Delphi Study - Retired Teachers Advise Adolescents* (Donaldson, Sheehan, et al., 2022a, submitted for publication) was discussed. The study aimed to elicit recommendations to manage physical activities and mitigate sedentary behaviors before age 65 to optimize healthspan when aged ≥ 65. The objective of a Delphi project is to identify a consensus by collecting valid expert opinions (Keeney et al., 2011; Niederberger & Spranger, 2020). A mixed methods Delphi project enabled the expert collaboration of nine panelists, all retired high school teachers aged ≥ 65, to generate eleven recommendations.

The e-Delphi project was a positive way of collaborating with key informants. The panel observed that youthful exposure to toxic substances, violent sports, abusive relationships, and indolent vocations was associated with diminished PA and increased sedentary practices throughout the lifecourse, culminating in compromised health, dysfunctionality, and annoyances in later life. Conversely, the panel observed that routine and balanced involvement with non-contact sports and activities, physically active companions, and active vocations increased the likelihood of optimal embodied health, functionality, and happiness in later years. The panel observed that physically educating the body and education about the body, having fun, traveling, and engaging in wilderness pursuits increased healthful practices and that too much time is spent on digital devices.

5.4.2 Future Directions

Delphi-generated recommendations are expert-based, curated retrospective distillations of older adults' memories with greater validity than random guessing because the recommendations

are based on memories of empirical experiences. The recommendations of this Delphi project are hypotheses for adults ≥ 65 to live a healthful lifestyle by optimizing the benefits of engaging in physical activities and mitigating damage from sedentary behaviors before reaching 65 years of age. The eleven Delphi expert-generated recommendations of this study are credible hypotheses to be examined with survey research and scientifically controlled trials.

Some of the recommendations generated by this Delphi project evolved over decades, the testing of which can be tested through longitudinal studies. The costs of longitudinal studies may now be significantly less with modern technologies for collecting and managing big data.

5.4.2.1 *Avoid addictive substances*.

This recommendation received twice the assertions as the panel's second-rated recommendation. In Canada, over 21% of the population meets the criteria for addiction at some time in their lifetime (Canadian Mental Health Association, 2022). The panel warned against excessive screen time as well as chemical addictions. Physical activity increases neurotransmitters in the brain that promote rewarding pleasurable sensations (Lembke & Raheemullah, 2019; Linke & Ussher, 2015; Lynch et al., 2013). Research is needed to determine the impact of addiction before age 65 on engagement in PA and the health of adults ≥ 65.

5.4.2.2 Avoid injuries when young.

Falls are the leading cause of injury-related death among adults ≥ 65 years old in the United States (Centers for Disease Control and Prevention, 2022). Research is needed to explore the relationships between injuries incurred before age 65 and the impact of those youthful injuries on PA engagement and health when ≥ 65 years. Such knowledge can inform risk assessments for decisions about participation in sports and recreation activities throughout the lifespan.

5.4.2.3 *Lead a balanced life.*

The Delphi panel recommended the coordination of work with recreational and physical activities. Research is needed to study the impact of early life strategies and dosages on the health of adults ≥ 65 years to balance PA and SB. For example, what is the optimal balance of desk standing, sitting, and walking on under desk treadmills? With the increasing availability and precision of voice assistants such as Apple's Siri, Amazon's Alexa, Microsoft's Cortana, and Google's Assistant that can free students and office workers from keyboard reliance, novel strategies should be researched that compare current desk work while being physically active to the propensity to engage in PA when ≥ 65 years.

5.4.2.4 Make activity routine.

Muscles less mobilized atrophy (Appell, 1990), but research is needed to refine and learn how the practice, implementation, and adherence to routines before age 65 later impact health and PA engagement of adults ≥ 65 years. Research is needed on routine practices of PA and SB before 65 years of age and their variation with socioeconomic status and the PL factors of competency, motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engaging in physical activities for life (Whitehead, 2019a). It would be informative to learn whether routine adherence of PA before age 65 impacts routine adherence of PA ≥ 65 years.

5.4.2.5 *Educate your body.*

This recommendation suggests that adults < 65 who condition their bodies to accommodate and exploit stresses and opportunities for PA engagement will experience health benefits and PA engagement when they are adults ≥ 65. Research is needed on the impact of PA engagement when under 65 on attitudes and practice when ≥ 65. Can the body of an adult ≥ 65

be conditioned to engage in PA more rapidly and with less injury when stretching, running, and lifting if the body experienced similar and different practices when the adult was < 65?

5.4.2.6 *Enjoy physical activity.*

Choose activities that are fun and not a chore. More research is needed to identify the impact of PA enjoyment when under 65 years on adults ≥ 65 years.

5.4.2.7 Seek companionship and sharing.

This recommendation directs research to explore the impact of physical activities while socializing before age 65 on PA engagement when ≥ 65. Sharing PA experiences on social network sites has increased social connectedness (Zuo et al., 2021). Research is needed to explore how sharing values and practices toward PA engagement and SB before age 65 persist and impact adherence and practices toward PA and SB when ≥ 65?

5.4.2.8 *Travel and move in the wilderness.*

This recommendation proposes that engagement in PA for ulterior motives such as cycling for transportation (Fishman et al., 2015) will result in increased PA engagement when ≥ 65. The author of this dissertation engaged in overland adventure travel for several decades before age 65. It typically involved overland travel by truck in small groups of 10-15 travelers. When arriving at a town or tourist destination, the travelers were given a half-hour talk and walk about town and then left to explore the remainder of the day on their own. Such explorations typically involved 4-6 hours of walking. Group activity days typically involved cycling and hiking. I don't recall anyone engaging in walking, cycling or hiking for the sake of exercise. Walking was transportation, a means to an end and not an end itself. Research is needed to explore whether PA engagement during travel and wilderness experiences while < 65 later impacts PA engagement and health when ≥ 65.

5.4.2.9 *Move instead of resting*.

The panel recommended mowing lawns by hand instead of using an externally powered lawnmower, removing snow with a hand shovel and not a snow blower, and vacuuming and mopping floors by hand rather than using a vacuum robot. Research is needed to compare the healthfulness and PA engagement of participants aged ≥ 65 who did laborious chores by hand before age 65.

5.4.2.10 Go it alone.

This recommendation suggests that, even when alone, PA engagement before age 65 increases the healthspan and PA engagement when aged ≥ 65. The percentage of American adults > 18 living alone in 2018 was 15% (United States Census Bureau, 2021). Research is needed to identify how circumstances and environmental variables that impact decisions of adults < 65 to engage in PA when alone impact later health and PA engagement when aged ≥ 65.

5.4.2.11 Be selective in friendships.

This recommendation suggests that association with friends before age 65 who value and encourage PA engagement results in greater PA engagement when aged ≥ 65. Spending time with friends while engaged in PA is important to maintain PA activity (Jago et al., 2009), and higher PA engagement of individuals has been associated with higher PA engagement among friends (Sawka et al., 2013). Research is needed to learn whether PA engagement with friends who value and encourage PA engagement when < 65 will result in greater individual PA engagement when aged ≥ 65.

5.5 Overall Conclusion

The findings of this dissertation supported Margaret Whitehead's work and philosophy that PA is holistically integral to being human and that plentiful PA is important for the human

body's healthy functioning, including the human brain. The compelling result of the high validity RCT Bike Study showed engagement in PA when accompanied by another enjoyable activity, interactive exergaming emphasized the need to broaden our investigation of PL. As seen in the Cycling Study, there is a holistic relationship between motivation of enjoyment and exergaming while cycling. The last project was a novel approach to e-Delphi for gleaning advice that generated multiple recommendations to optimize PA and mitigate SB to achieve a happier and longer healthspan.

5.6 Contributions to Knowledge

The analyses presented in this dissertation have advanced knowledge and understanding in three important ways:

1. Philosophical speculations that underpin the epistemological foundations of the physical literacy paradigm were supported with claims of scientific evidence.
2. Comparisons of the two cycling interfaces - 2D monitor and 360° headset - showed that both conditions increased motivation to engage in PA while exergaming. This finding that both interfaces increased motivation equally has important implications for the design and development of exergaming systems.
3. The effective use of the e-Delphi technique with a panel of educational experts demonstrated its value as a mixed-methods research tool in kinesiology. The e-Delphi Method enabled expert collaboration to generate recommendations for healthier lifespans by managing physical and sedentary behaviors across the lifespan**.**

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Appendices

Appendix usually means "small outgrowth from large intestine," but in this case it means "additional information accompanying main text." Or are those really the same things? Think carefully before you insult this book.” (Bosch, 2008)

Appendix A – Cycling Poster to Inform and Recruit VR Bike Participant

Come Ride with Us!

Stationary Bike Riding Research

- We test enjoyment of riding a stationary bike and playing an interactive game.
- If you are 65 years old or over in good health, we welcome your participation.
- 1st - You will fill in a pre-participation questionnaire about your health.
- 2nd If in good health, you will read and sign a consent letter.
- 3rd You ride a stationary cycle for 5 minutes without playing a game.
- 4th You rest for 5+ minutes while answering a few questions about your ride.
- 5th You ride a stationary cycle for 5 minutes while playing an interactive game.
- 6th You rest while answering questions about your enjoyment of that ride.

Tell Recreation Convener that you want to do this. We will get back to you.

Call to action/Important event details
Date | Time
Location
RSVP instructions/deadline

UNIVERSITY OF CALGARY
FACULTY OF KINESIOLOGY

This study has been approved by the University of Calgary Conjoint Health Research Ethics Board. Ethics ID: **REB18-1474**

Appendix B - AHA/ACSM Fitness Screening Questionnaire

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire *

Assess your health status by ticking all true statement with a check mark. (✓)

HISTORY

You have had

- ☐ a heart attack.
- ☐ heart surgery.
- ☐ cardiac catheterization.
- ☐ coronary angioplasty (PTCA).
- ☐ pacemaker/implantable cardiac defibrillator/rhythm disturbance.
- ☐ heart valve disease.
- ☐ heart failure.
- ☐ heart transplantation.
- ☐ congenital heart disease.

SYMPTOMS

- ☐ You experience chest discomfort with exertion.
- ☐ You experience unreasonable breathlessness.
- ☐ You experience dizziness, fainting, or blackouts.
- ☐ You take heart medications.

OTHER HEALTH ISSUES

- ☐ You have diabetes.
- ☐ You have asthma or other lung disease.
- ☐ You have burning or cramping sensation in your lower legs when walking short distances.
- ☐ You have musculoskeletal problems that limit your physical activity.
- ☐ You have concerns about the safety of exercise.
- ☐ You take prescription medications.
- ☐ You are pregnant.

CARDIOVASCULAR RISK FACTORS

- ☐ You smoke, or quit smoking within the previous 6 months.
- ☐ You have had a hysterectomy or are postmenopausal.
- ☐ Your blood pressure is >140/90 mmHg.
- ☐ You do not know your blood pressure.
- ☐ You take blood pressure medication.
- ☐ Your blood cholesterol level is >200 mg/dL.
- ☐ You do not know your cholesterol level.
- ☐ Your [father/brother before age 55] or [mother/sister before age 65] had a heart attack or heart surgery.
- ☐ You are diabetic or take medicine to control your blood sugar.
- ☐ You are get LESS THAN 30 minutes of physical activity on at least 3 days per week.
- ☐ You are >20 pounds overweight.
- ☐ None of the above

* AHA/ACSM indicates American Heart Association/American College of Sports Medicine.

Appendix C - Cycling Letter of Consent

UNIVERSITY OF CALGARY

CONSENT FORM

TITLE: A Study of The Impact of Immersive Exergaming on Enjoyment of Older Adults

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 for your records.

INVESTIGATORS:

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BACKGROUND

To maintain a healthy lifestyle, it is important to be physically active. We are more likely to remain physically active if we enjoy doing physical activity. An active lifestyle helps us stay healthy, be comfortable and be motivated to continue being physically active.

Games provide enjoyment. When we experience enjoyment while playing a game, we spend more time playing the game than if we didn't enjoy it. Computer fitness games that provide enjoyment while exercising can motivate us to spend even more time exercising.

For years people have enjoyed riding stationary fitness bikes while playing interactive computer games that respond to the way the bike is ridden and steered. Stationary fitness bikes let riders play interactive games while viewing a computer monitor. Today there are also stationary fitness bikes that let riders play interactive games while wearing a virtual reality helmet.

It will be interesting to learn whether riders get more enjoyment from playing computer exercise games while watching a monitor or while wearing a virtual reality helmet.

CONSENT FORM

UNIVERSITY OF CALGARY

WHAT IS THE PURPOSE OF THE STUDY?

You are being asked to participate in a research study entitled: ***A study of Immersive Exergaming on Enjoyment among Older Adults***. The purpose of this research study is to test the impact of immersive exergaming on enjoyment of older adults while riding a stationary exercise bike.

WHAT WOULD I HAVE TO DO?

Arrive for riding a stationary fitness bike wearing comfortable shoes and loosely fit clothing.

We'll ask a few questions about health and heart related problems. If we think there are serious problems, we will ask you to see your doctor about the problems before you ride the bike.

We'll ask you to wear an Apple Watch that records your heart rate while riding the bike.

We'll show you how to ride the bike while not playing a game. Then you'll ride for 5 minutes.

We'll give you a rest while you answer some paper-and-pencil questions about your first ride.

We'll show you how to ride the bike while you do play a game. Then you'll ride for 5 minutes.

We'll ask you to answer some more paper-and-pencil questions about your second ride.

WHAT ARE THE RISKS?

If you are in good health and there are no concerns about your heart, there should be no physical risks.

ARE THERE ANY BENEFITS FOR ME?

There is no immediate benefit to the participant. In appreciation of your support for this study, after you finish the second ride, you are welcomed to continue playing the game for 10 minutes.

DO I HAVE TO PARTICIPATE?

Your participation in this research study is completely voluntary You may stop at any time for any reason. Just let the investigator know. Withdrawing from the study means that any information that has been collected related to the research will be destroyed.

WHAT ELSE DOES MY PARTICIPATION INVOLVE?

There is no cost associated with participation in this study, there is also no remuneration.

CAN DATA COLLECTED ON PARICIPANTS BE WITHDRAWN?

Data can only be withdrawn up until the point that your study team begins analyzing the data.

WILL MY RECORD BE KEPT PRIVATE?

All participants will receive a randomized number that will be the only connection to the collected information. The name of each participant and their corresponding code shall be locked in a separate secure cabinet from the information collected during experiment. All field notes, journals, videos or observations shall remain in the co-investigator's possession or securely locked in a filing cabinet inside the co-investigators office.
Final results will be shared publicly in the University of Calgary for academic proposes. It is also intended that the results will be presented at conferences and through written publications.
A description of this study will be available on http://www.ridevirtual.org/. The web site will include a summary of the results. You may search this web site at any time.

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 their participation as a subject. 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 penalty. If you have further questions concerning matters related to this research, please contact:

Gerry Donaldson, PhD Student, University of Calgary, 403-284-4294, gerrydonaldson@gmail.com.
Larry Katz, PhD, Professor (Supervisor), University of Calgary, 403 220-3418 katz@ucalgary.ca.

If you have any questions concerning your rights as a possible participant in this research, please contact The Chair of the Conjoint Health Research Ethics Board, University of Calgary at 403-220-7990.

AGREEMENT TO PARTICIPATE

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 their participation as a subject. 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 penalty. If you have further questions concerning matters related to this research, please contact:

Gerry Donaldson, PhD Student, University of Calgary, 403-284-4294, gerrydonaldson@gmail.com.
Larry Katz, PhD, Professor (Supervisor), University of Calgary, 403 220-3418 katz@ucalgary.ca.

If you have any questions concerning your rights as a possible participant in this research, please contact The Chair of the Conjoint Health Research Ethics Board, University of Calgary at 403-220-7990.

Participant's Name	Signature and Date
Investigator/Delegate's Name	Signature and Date
Witness' Name	Signature and Date

The investigator or a member of the research team will, as appropriate, explain to you the research and your involvement. They will seek your ongoing cooperation throughout the study. 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 D – Cycling – "Friendly Pilot" Samples & Analyses

This appendix contains an exploratory planning analysis prepared in 2018.

D.1 Friendly Pilot Data

In September 2018, the first author conducted a small "Friendly Pilot" with nine relatives and friends to practice and refine trial procedures. During this "Friendly Pilot," measures were obtained, which, while invalid for analysis due to ongoing changes in procedures during the pilot, nevertheless offered guidance for determining a plausible sample size. (See Tables D15 and D16.)

The Friendly Pilot offered a sandbox for designing and testing procedural implantation.

Table D15 – *Pilot Data while riding the Expresso Bike with a 2 Dimensional Monitor*

Mixed Reality with Expresso Bike & 2 Dimensional Computer Monitor																
			Ride 1							Ride 2						
		Date	Natural Reality = Manual Blank Screen							Mixed Reality = Dragon Game						
		Sept	Apple Watch 3					OxyWatch		Apple Watch 3					OxyWatch	
Subj	Sex	2018	Min	Max	x̄	Joy	Diff	Pulse Rate		Min	Max	x̄	Joy	Diff	Pulse Rate	
[redacted]	M	9th	62	78	72	34	3.5	55	102	127	138	132	49	5.5	80	113
	M	10th	73	107	89	35	2	73	96	97	103	98	29	3	73	96
	M	12th	61	101	92	32	2	~~96~~	104	88	105	99	36	2	~~95~~	105
	M	14th	112	118	114	39	2			97	112	121	56	3		
	F	16th	100	164	144	28	3			88	156	142	38	2	88	156
	M	17th	93	116	111	42	3			84	122	115	20	4		
	F	21st	x	x	x	30	9			76	98	89	8	10		
	M	26th	71	87	78	20	1	57		74	149	126	37	10		
	F	29th	77	101	87	26	1	55		65	101	96	30	2		
Total			649	872	787	286	26.5			796	1084	1018	300	41.5		156
x̄			81.1	109	98.4	31.8	2.9			88.4	120.4	113.1	33.3	4.61		
			Max Possible →			56	10			Max Possible →			56	10		

Table D16 - *Pilot Data while riding the VirZOOM Bike with VR Headset*

Virtual Reality with VirZOOM Bike & Samsung HMD Odyssey Headset																	
			Ride 3							Ride 4							
		Date	Natural Reality = Manual Blank Screen							Virtual = Thunder Bowl (Tank) Game							
		Sept	Apple Watch 3					OxyWatch		Apple Watch 3					OxyWatch		
Subj	Sex	2018	Min	Max	x̄	Joy	Diff	Pulse Rate		Min	Max	x̄	Joy	Diff	Pulse Rate		
[redacted]	M	9th															
	M	10th	90	111	103	22	3	MS	103	82	116	99	30	4	MS	MS	
	M	12th	73	116	97	26	3	x	x	83	100	93	28	3	x	104	
	M	14th	108	120	119	35	3			102	110	106	41	2	92		
	F	16th	74	145	92	25	3			94	167	142	48	2	62	92	
	M	17th	78	114	108	14	3			72	115	101	48	4			
	F	21st	77	93	86	52	4			72	85	77	56	1			
	M	26th	95	103	100	20	2			86	133	124	42	3			
	F	29th	x	x	x	23	1			x	x	x	23	1			
Total			595	802	705	217	22			561	826	742	316	20			
x̄			85	114.6	100.7	27.1	2.75			80.1	137	106	39.5	2.5			
			Max Possible →			56	10			Max Possible →			56	10			

D.2 Sample Criteria

This phase of the study can use a convenience sample of sixty older adults (65+) in senior citizen living residences in Calgary and/or service centers such as the "Calgary Kerby Centre." Excluded will be those for whom screening indicates a health or cardiovascular risk.

Inclusion Criteria. Participants who have reached 65 years of age whose responses to the pre-participation screening questionnaire indicate the absence of health risk or cardiovascular risk, including abstention from smoking any substance or use of e-cigarettes or vaporizers, will be included.

Exclusion Criteria**.** Those who have not reached 65 years of age and those whose responses to the pre-participation screening questionnaire indicate a health risk or cardiovascular risk, and those who smoke anything, use e-cigarettes or vaporizers.

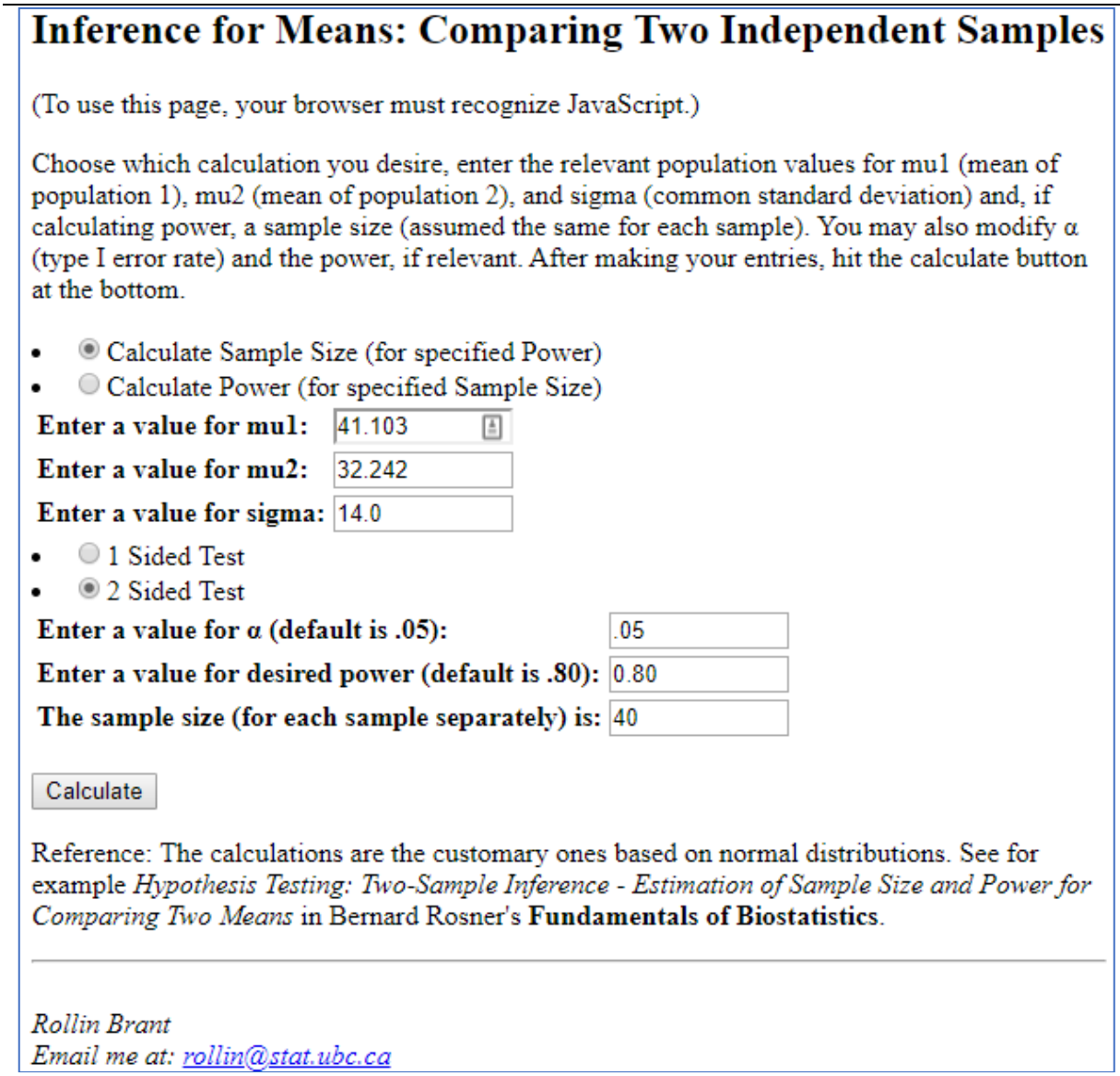
D.3 Sampling Technique and Size

There will be two independent samples with measures for Enjoyment. One group will see participants ride the Expresso Bike with measures of Enjoyment for a Natural Reality Test ride (pre-enjoyment) and a Mixed Reality Test ride (post-enjoyment); the other group with measures of Enjoyment taken for a Natural Reality Test ride (pre-enjoyment) and a Virtual Reality Test ride (post-enjoyment). The sample size has been calculated with α=0.05, β=0.20, power = 0.80, range = 56, σ = 14, Δ = 8.861. The standard deviation is estimated to be σ = 56/4 = 14, approximated from the "range rule" when applied to the total possible score on the Mullen *Older Adult Physical Activity Enjoyment Scale (Table E6)* found at (Mullen et al., 2011). The derived value of Δ=8.861 was the difference found in the Friendly Pilot between the adjusting means of the two groups on the Mullen *Older Adult Physical Activity Enjoyment* Scale found at (Mullen et al., 2011). The sample size is calculated for these two independent samples given the above values of the parameters for the two groups. (Lachin, 1981, p. 96).

$$n = \frac{2\sigma^2 (Z_\beta + Z_\alpha)^2}{\Delta^2} = \frac{2(14)^2 (0.84 + 1.96)^2}{(41.103\text{-}32.242)^2} = \frac{2(196)(7.84)}{(8.861)^2} = \frac{3073.28}{(78.517)} = 39.14 \approx 40$$

This calculation is corroborated by the following Brant (2018) automated calculation (Figure D10).

Figure D10 - *Comparing Two Sample Means Between Mixed & Virtual Reality*



Inference for Means: Comparing Two Independent Samples

(To use this page, your browser must recognize JavaScript.)

Choose which calculation you desire, enter the relevant population values for mu1 (mean of population 1), mu2 (mean of population 2), and sigma (common standard deviation) and, if calculating power, a sample size (assumed the same for each sample). You may also modify α (type I error rate) and the power, if relevant. After making your entries, hit the calculate button at the bottom.

- ◉ Calculate Sample Size (for specified Power)
- ○ Calculate Power (for specified Sample Size)

Enter a value for mu1: 41.103

Enter a value for mu2: 32.242

Enter a value for sigma: 14.0

- ○ 1 Sided Test
- ◉ 2 Sided Test

Enter a value for α (default is .05): .05

Enter a value for desired power (default is .80): 0.80

The sample size (for each sample separately) is: 40

Calculate

Reference: The calculations are the customary ones based on normal distributions. See for example *Hypothesis Testing: Two-Sample Inference - Estimation of Sample Size and Power for Comparing Two Means* in Bernard Rosner's **Fundamentals of Biostatistics**.

Rollin Brant
Email me at: rollin@stat.ubc.ca

Prior proximate differences Δ in the mean scores of Enjoyment between the Natural Reality Test and Mixed Reality Test and between the Natural Reality Test and Virtual Reality Test are not found in the literature; thus, an exploratory study was used to derive proximate differences empirically.

The following table illustrates needed sample sizes if true differences between the two groups are found in dependent variables with mathematically different totals. See Table D17

D.4 Estimate Sample Size-Dependent on Mean Difference in Two Sample Means*

Table D17 - *Sample size at alpha=0.05 when comparing means of two independent samples.*

Dependent Variables	Empirical Referent	Typical Range	Sigma 2-Sided Test [4]	Adjusted Mean Difference To Detect	Power [5] Reject Type 2 Error. Reject H0 when H1 is true. 0.80	0.85	0.90	0.95
Enjoyment	Mullen's Scale [1]	0 - 56	14	8.861	40	45	53	66
Perceived Effort	Cleveland Scale [2]	1 - 10	2.5	1.749	33	37	43	54
Actual Effort	Average Heart Beat [3]	90 - 135	14.012	26.215	16	18	22	26
Actual Effort	Minimum Heart Beat [3]	70 - 106	9.0	11.685	10	11	13	16
Actual Effort	Maximum Heart Beat [3]	98 - 145	11.75	11.837	16	18	21	26

1. Mullen Enjoyment Scale.

2. Cleveland Scale of Perceived Physical Exertion. A normal resting heart rate for adults ranges from 60 to 100 beats per minute (Laskowski, 2018).

3. Participant's Heartbeat is measured, recorded, and presented with operations of a Strava App operating on an Apple Watch, Series 3, while the participant rides.

4. The "range rule" is used to approximate the standard deviation, calculated by dividing the range by 4.

5. Power is the probability that a test correctly rejects the null hypothesis (H0) when an alternative hypothesis (H1) is true. As power increases, the probability of wrongly failing to reject the null hypothesis decreases (Vincent & Weir, 2012, pp. 94-95).

* Source: Lachin, John M. (1981). Introduction to Sample Size Determination and Power Analysis for Clinical Trials. *Contemporary Clinical Trials*, 2(2), 93-113.

This study will gather data from two groups (Table D18), each with 20 randomly assigned participants, 20 males, and 20 females, for a total of 40 participants. Participants of each group will do two rides on one bike and not ride the other bike at all.

Table D18 - *Levels of Visual Virtual Immersiveness on a Stationary Fitness Bike*

Visual Virtual Immersiveness Bike	Reality	Exergaming Environment	Gaming Activity While Riding A Stationary Fitness Bike
Expresso	Natural	None	No Gaming & No Other Stimulation.
	Mixed	19" Monitor	Chase Fitness Game
VirZOOM	Natural	None	No Gaming & No Other Stimulation.
	Virtual	360° Helmet	Chase Fitness Game

There are two conditions for each bike: riding with no stimulation and riding with either "Mixed Reality" (Expresso Bike) or "Virtual Reality" (VirZOOM Bike**)**.

D.5 Measures

Independent variable. Two experimental conditions of Visual Virtual Immersiveness (VVI) while riding a stationary fitness bike while exergaming:

(1) Mixed Immersive Exergaming while riding an Expresso Stationary Fitness Bike.

(2) Virtual Immersive Exergaming while riding a VirZOOM Stationary Fitness Bike.

5.6.1.1 Dependent variables.

(1) Mullen et al. (2011) *Older Adult Physical Activity Enjoyment Scale*.

(2) Perceived Effort as measured by the Cleveland Clinic Revised Rating of Perceived Exertion (Cleveland_Clinic, 2013).

(3) Actual Effort by Exertion as measured by an Apple Watch Series 3, recorded on the Apple Watch Series 3 in the app Strava. Following stopping the recoding by the Strava app, the data is transferred via Bluetooth to an iPhone, whereupon it is uploaded to the personal Strava account of the researcher. There, while logged into the personal Strava account of the researcher, a chart for each ride is accessible, which shows the minimum, maximum and average heartbeat during the ride. (See Figure 2 and Figure 3.)

D.6 Procedure

Participants will be screened using the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire (Balady et al., 1998). Participants passing the screening will be asked to sign a letter of consent to participate.

Table D19 illustrates sequences of rides on each of two stationary fitness bikes: the Mixed Reality Bike and the Virtual Reality VirZOOM Bike. Each sequence requires one ride in Natural Reality (no gaming or other external stimulation) and one ride in either Mixed Reality while exergaming or in Virtual Reality while exergaming.

One group, the "Expresso Bike Group," will first peddle the Expresso Bike without gaming or other visual stimulation and then peddle the Expresso Bike while playing an interactive electronic chase game "Dragon."

The other group, the "VirZOOM Bike Group," will first peddle the VirZOOM Bike without gaming or other visual stimulation and then peddle the VirZOOM Bike while playing the Virtual Reality game "Thunder Bowl."

Table D19 – *Ride Sequences on MR Expresso Bike & VR VirZOOM Bike*

Mixed Reality: Expresso Bike	**1st Ride**	**2nd Ride**
	Natural Reality No Exergaming	**Mixed Reality Dragon Game**

Virtual Reality: VirZOOM	**1st Ride**	**2nd Ride**
	Natural Reality No Exergaming	**Virtual Reality Thunder Bowl**

Appendix E- Cycling - Expresso Interactive Upright Fitness Bike - S3U

Figure E11 - *Expresso Interactive Upright Fitness Bike - S3U*

Expresso Mixed Reality Cycle Used in the Study

The Mixed Reality cycle (Figure E11) used in the study was an upright stationary exercise bicycle electronically integrated with a 2D display featured on a 19-inch computer monitor. The bike features 30 different gears. Resistance automatically adjusts to the terrain on the screen. A dashboard on the screen displays speed, time played, power, and heart rate.

E.1 Dragon Chase Interactive Game

The Expresso S3U bike has only one interactive game: The Dragon Chase Game. The Expresso Dragon Chase game is a fixed-time, off-road course. Riders score points by chasing down coins of different colors, followed by chasing down a dragon matching the color of the last secured coin. Riders follow a yellow arrow that points to a dragon of the pursued color. Score or speed can be increased exponentially for a brief period by chasing a down lantern object. Similarly, the pursued dragon can be rendered sluggish by running down an object resembling a dazed dragon. Points earned depend on the color of the dragon. Chasing down a red dragon earns 100 points, a blue dragon 300 points, a red dragon 500 points, and a silver dragon 1000 points.

Appendix F – Cycling - VirZOOM Virtual Reality Fitness Bike

The VirZOOM Bike is a game controller with integrated speed and direction sensors (Figure F12). The VirZOOM Bike Controller is wireless via Bluetooth connectivity, measures heart rate, offers eight tension control resistance settings, weighs 39 pounds, and folds up for easy storage. Buttons on the handlebars allow you to interact with game worlds, and your pedaling speed on the bike controls your movement speed in games.

Figure F12 - *VirZOOM Virtual Reality Fitness Bike*

F.1 Games in the VirZOOM Arcade

Cowboy: Jailbreak! Lasso bandits off horses and throw dust devils.

Kayak: Lotus Pond. Find ducks during the day, and at night lead fish to underwater gems.

Cycle: Le Tour, Cali Rally. Ride in a bicycle race, drafting behind other cyclists.

Racecar: Race AI, live players online, and the ghosts of your own best laps on different tracks.

Tank: Winterstan. Battle against tanks and mechs controlled by AI.

Tank: Thunder Bowl. A head-to-head multiplayer tank battle

Pegasus: Search for gems, skim treetops for apples, and race through canyon gates.

Chopper River Run. Shoot turrets, dodge missiles, and keep fueled to stay in the air.

Appendix G – Cycling - Interactive Fitness Consent to Use Images of Expresso Bike

G.1 Permission from VP of Global Sales, Interactive Fitness Holdings

Gmail Gerry Donaldson <gerrydonaldson@gmail.com>

Please give me permission to use two images in my Ph.D. dissertation.

[redacted]@ifholdings.com> 25 March 2022 at 12:41
To: Gerry Donaldson <gerrydonaldson@gmail.com>

Hi – you have permission!!!

Thanks!

From: Gerry Donaldson <gerrydonaldson@gmail.com>
Sent: Friday, March 25, 2022 9:45 AM
To: support <support@ifholdings.com>; marketing@ifholdings.com; sales@ifholdings.com
Subject: Re: Please give me permission to use two images in my Ph.D. dissertation.

May I have your permission to reproduce the image below?

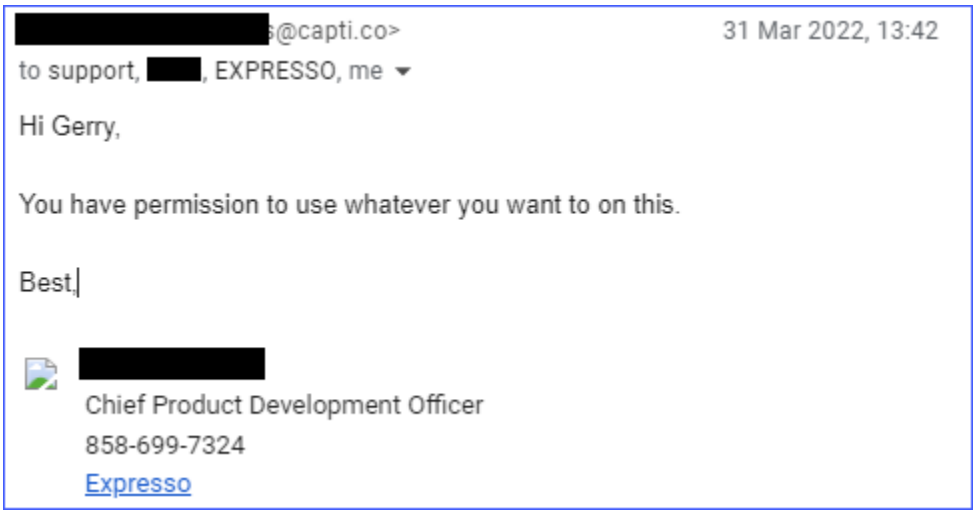
Gerry.

PS: I also need permission and a link to an image of somebody riding an Expresso SU3 bike.

Permission from VP of Global Sales, Interactive Fitness Holdings (continued)


Time
2:56
Score
270

G.2 Permission from Chief Product Development Officer, Interactive Fitness Holdings



[redacted]@capti.co> 31 Mar 2022, 13:42

to support, [redacted], EXPRESSO, me

Hi Gerry,

You have permission to use whatever you want to on this.

Best,

[redacted]

Chief Product Development Officer

858-699-7324

Expresso

Appendix H – Cycling - VZFit Consent to Use Images of VirZOOM Bike

H.1 Permission from VZFit Support, VirZOOM Co.

Gmail Gerry Donaldson <gerrydonaldson@gmail.com>

[VZFit Support] Re: Request Permission to Put Images of VirZOOM Bike in Dissertation

[redacted] (VZFit Support) <support@virzoom.zendesk.com> 5 October 2021 at 23:30
Reply-To: VZFit Support <support+id3711@virzoom.zendesk.com>
To: Gerry Donaldson <gerrydonaldson@gmail.com>

Please type your reply above this line

Your request (3711) has been updated. To add additional comments, reply to this email.

[redacted] (VZFit Support)
Oct 6, 2021, 1:30 AM EDT

Hi Gerry,

Thanks for asking permission. We'd be happy to allow you to publish any and all photos you like.

Looking forward to checking out the dissertation.

Best,

[redacted]

Gerry Donaldson
Oct 5, 2021, 5:59 PM EDT

At this time I am completing my Ph.D. dissertation and authoring an academic article to be published in a peer-reviewed journal. I did a Random Controlled Trial (RCT) to study the enjoyment of Virtual Reality Exergaming. During the trials, a group of my participants rode my VirZOOM Bike.

I would like permission from VirZOOM to copy one or more of the images found on the attached pdf file, for inclusion in my dissertation and hopefully in an article in a peer-reviewed journal that I am writing that is based on the VR Enjoyment study that I did for my Ph.D. dissertation. There are two different images of a man riding an original VirZOOM Bike and two images of the entire original VirZOOM Bike.

The following legalese is meant to be specific about what is requested.

Permission from VZfit Support, VirZOOM Co. (continued)

The requested permission extends to any future revisions and editions of my dissertation, including nonexclusive world rights in all languages, and to the prospective publication of my dissertation. I may produce and sell copies of my dissertation on demand and may make my dissertation available for free internet download at my request. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your permission will also confirm that you own [or your company owns] the copyright to the above-described material. If these arrangements meet with your approval, please confirm your approval by replying in the affirmation to this email.

I would greatly appreciate VirZOOM's permission to reproduce one or more of the images. I will remit to you and VirZOOM a copy of my dissertation and the published article when they are published.

Thank you very much.

Sincerely,

Gerry.

Gerry Donaldson, Ph.D. Candidate

Faculty of Kinesiology,

University of Calgary,

Calgary, Alberta, T2N 1N4

Virtual Reality Lab, KNA 121

Submitted from: https://www.vzfit.com/

Attachment(s)
Images of VirZOOM Bike.pdf

Appendix I – Cycling - Mullen Older Adult Physical Activity Enjoyment Scale

Mullen et al. (2011) later validated a shortened, 8-item, psychometrically sound version of PACES in a sample of older adults (Table E20), twice assessing two exercise groups six months apart, giving us an instrument validated for assessing enjoyment in physical activity with older adults.

Replicated from Mullen et al. (2011, p. 6) Adapted from (Kendzierski & DeCarlo, 1991)

Table E20 - *Mullen Older Adult Physical Activity Enjoyment Scale*

Below are pairs of statements that describe how you felt about the ride you just did. Place a checkmark (✓) between each pair. The closer your mark is to a description, the stronger your feeling towards how the description describes how you felt.

I find it pleasurable.	( )	( )	( )	( )	( )	( )	( )	I find it unpleasurable.
It's a lot of fun.	( )	( )	( )	( )	( )	( )	( )	It's no fun at all.
It's very pleasant.	( )	( )	( )	( )	( )	( )	( )	It's very unpleasant.
It's very invigorating.	( )	( )	( )	( )	( )	( )	( )	It's not at all invigorating.
It's very gratifying.	( )	( )	( )	( )	( )	( )	( )	It's not at all gratifying.
It's very exhilarating.	( )	( )	( )	( )	( )	( )	( )	It's not at all exhilarating.
It's very stimulating.	( )	( )	( )	( )	( )	( )	( )	It's not at all stimulating.
It's very refreshing.	( )	( )	( )	( )	( )	( )	( )	It's not at all refreshing.

Table E6 is replicated from Mullen et al. (2011, p. 6) as adapted from (Kendzierski & DeCarlo, 1991, pp. 62-63)

This is a "Semantic Differential Rating Scale" that uses parentheses, unlike a "Likert Scale" that uses numbers.

Scoring Format

I find it pleasurable.	1	2	3	4	5	6	7	I find it unpleasurable.
It's a lot of fun.	1	2	3	4	5	6	7	It's no fun at all.
It's very pleasant.	1	2	3	4	5	6	7	It's very unpleasant.
It's very invigorating.	1	2	3	4	5	6	7	It's not at all invigorating.
It's very gratifying.	1	2	3	4	5	6	7	It's not at all gratifying.
It's very exhilarating.	1	2	3	4	5	6	7	It's not at all exhilarating.
It's very stimulating.	1	2	3	4	5	6	7	It's not at all stimulating.
It's very refreshing.	1	2	3	4	5	6	7	It's not at all refreshing.

Table E20 is replicated from Kendzierski and DeCarlo (1991, pp. 62-63).
This is a "Semantic Differential Rating Scale" that uses parentheses. A "Likert Scale" uses numbers. The average score for each description defines a sort of "correlation" between the description and the object being tested.

Appendix J – Cycling - SDT Interest/Enjoyment Intrinsic Motivation Subscale

Source of this Appendix: SDT. (2018). Intrinsic Motivation Inventory (IMI). Retrieved on 26 November 2018 from http://selfdeterminationtheory.org/intrinsic-motivation-inventory/ (SDT, 2018)

1	2	3	4	5	6	7
Not True			Somewhat			Very True

I enjoyed doing this activity very much.

This activity was fun to do.

I thought this was a boring activity. (R)

This activity did not hold my attention at all. (R)

I would describe this activity as very interesting.

I thought this activity was quite enjoyable.

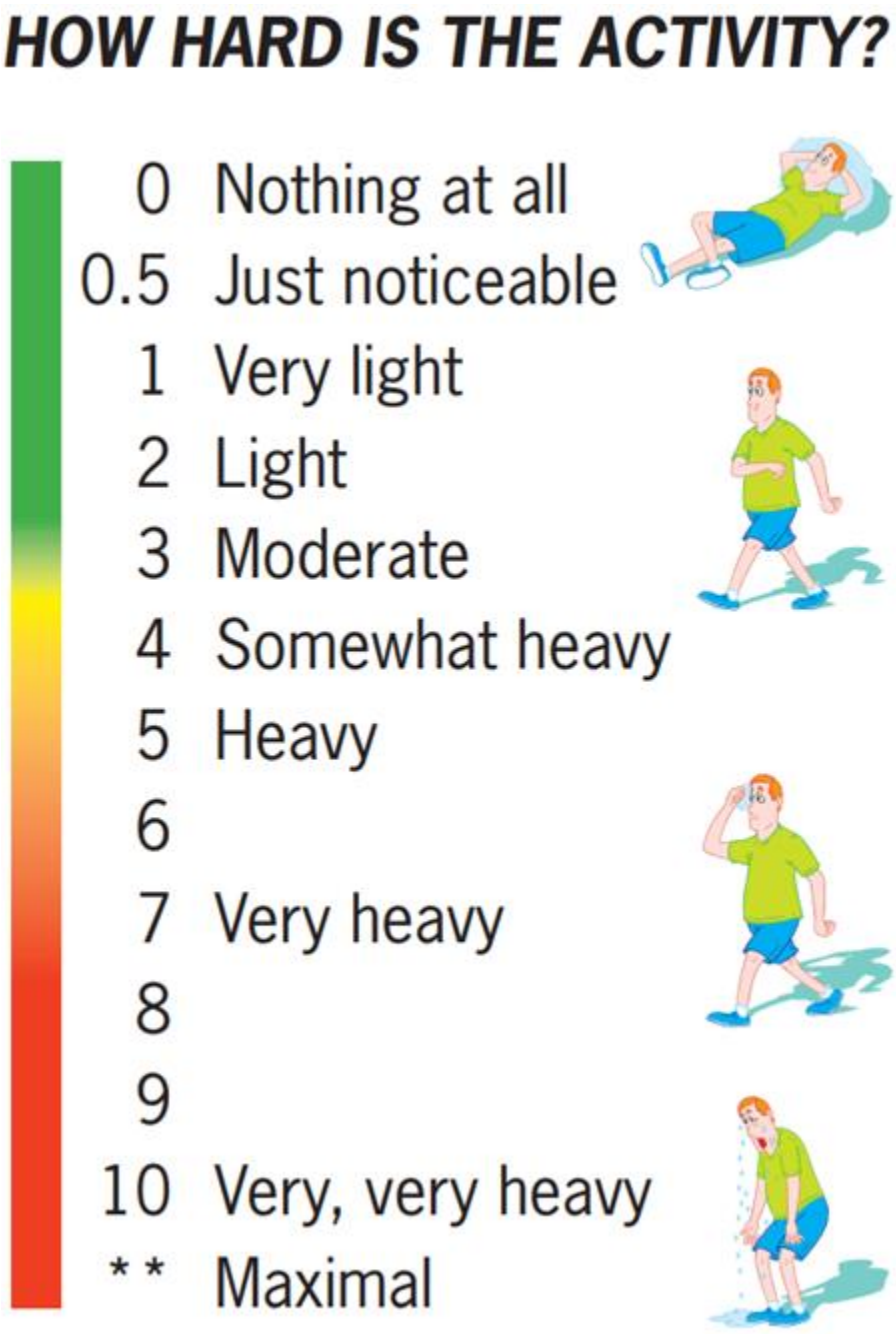
While I was doing this activity, I was thinking about how much I enjoyed it.

As one can readily tell, there is nothing subtle about these items; they are quite face-valid. However, in part, because of their straightforward nature, caution is needed in interpretation. We have found, for example, that correlations between self-reports of effort or interest and behavioral indices of these dimensions are quite modest--often around 0.4. Like other self-report measures, there is always the need to appropriately interpret how and why participants report as they do. Ego- involvements, self-presentation styles, reactance, and other psychological dynamics must be considered. For example, in a study by Ryan, Koestner, and Deci (1991), we found that when participants were ego involved, they engaged in pressured persistence during a free-choice period, and this behavior did not correlate with the self-reports of interest/enjoyment. In fact, we concluded that to be confident in one's assessment of intrinsic motivation, one needs to find that the free-choice behavior and the self-reports of interest/enjoyment are significantly correlated.

Another issue is that of redundancy. Items within the subscales overlap considerably, although randomizing their presentation makes this less salient to most participants. Nonetheless, shorter versions have been used and have been found to be quite reliable. The incremental R for every item above 4 for any given factor is quite small. Still, it is very important to recognize that multiple item subscales consistently outperform single items for obvious reasons, and they have better external validity.

Appendix K – Cycling - Cleveland Rated Perceived Exertion (RPE) Scale

Perceived Effort may be measured by the Cleveland Clinic Revised Rating of Perceived Exertion (Cleveland_Clinic, 2013).



Appendix L – Cycling - Real Effort == Heart Rate as Recorded Using the Apple Watch

The "gold standard" of heart rate monitors is a medical-grade EKG machine. During aerobic activities, chest strap monitors agree within 1-2 beats per minute (bpm) (Prospero, 2016) and wrist strap monitors within 2-3 bpm of a medical-grade EKG machine (Horton et al., 2017; Prospero, 2016). While riding a cycle ergometer in a UK study, an Apple Watch Series 1 was the most accurate wrist monitor, being within 2.2% of an EKG, whereas a Mio was at 4.4%, TomTom at 11.1%, and Fitbit at 21.1% (Hough, 2018). A recent Cleveland, OH study found that the Apple Watch provided the most accurate readings of wrist-worn HR monitors, with several watches at $r_c > .8$ while biking, but only the Apple Watch provided accurate readings ($r_c = .94$) on the elliptical trainer without arm levers (Gillinov et al., 2017).

In a 2016 study reported on the Tom's Guide website, journalist Mike Prospero, working with Dr. Suzanne Steinbaum, a cardiologist and Director of Women's Heart Health at the Heart and Vascular Institute of Lenox Hill Hospital in New York City, tested several wrist-based fitness trackers using a Quinton Cardiac Science Q-Stress test machine as a control. The Apple Watch, Series 1, was found to be within 2-3 beats per minute when compared to the EKG machine during resting, brisk walking, and running (Prospero, 2016). See Table L21.

Table L21 - *Fitness Trackers Compared for Accuracy in Heart Beats per Minute*

	Variance from EKG Machine		
Product	***Resting When 60 ≤ HR ≤ 80***	***Brisk Walking 120 < HR ≤ 130***	***Running 16 ≤ HR ≤ 170***
Apple Watch	2-3	2	2-3
Fitbit Blaze	1-2	2-3	2
Fitbit Charge HR	1-2	2-3	4
Garmin Forerunner 235	1-2	1-2	2-3
Garmin Viviosmart HR	2-3	1-2	2-3
TomTom Spark Cardio + Music	2-3	1-2	2-3
Polar H7	1	1-2	1-2

The team behind the Cardiogram app recently conducted a new study for the Apple Watch in conjunction with researchers at the University of California, San Francisco (Clover, 2018; Tison et al., 2018). Cardiogram's study argued that the Apple Watch alone, with 97% accuracy, does a better job of detecting abnormal heart rhythms than the FDA-approved accessory KardiaBand. In the Cardiogram study, the Apple Watch, which can read a heart rate every 5 seconds, was deemed to be more accurate than an EKG machine because it continually measures pulse rate over time rather than grabbing a snapshot in time (Marcus, 2018)!

The Apple Watch uses an optical heart rate (OHR) monitor to determine the pulse rate. When activated, Light Emitting Diodes (LED) sends light through the skin and measures the amount of returning light. Blood absorbs light, so variations in light that the sensors detect are used to determine the pulse rate (Apple, 2018).

Continuous Recording of Heart Rate with Strava App running on Apple Watch, Series 3

The Apple Watch's built-in Heart Rate monitor can be accessed and recorded using the Strava Apple App for the iPhone.

In September 2018, preparation trials for this study were conducted in an informal "Friendly Pilot" using relatives and friends of the researcher. Features and bugs in the procedure were tested, refined, some dismissed, some introduced, and some changed.

Pulse rate was recorded continuously with the Strava Apple App running on an Apple Watch, series 3, and transferred to an iPhone X linked by Blue Tooth to the Apple Watch. Pulse rate was also recorded at the beginning and end of several rides with an OxyWatch Pulse Oximeter. Recorded data from the Strava App revealed significant variation in heart rate over the entire ride, a variation that was not detected with only beginning and ending values taken

with the OxyWatch Oximeter. The OxyWatch Oximeter can display a participant's heart rate continuously but was deemed impractical to use for this purpose for two reasons.

(1) It is inconvenient, distracting, and unreliable to maintain a finger in an oximeter while riding.

(2) The oximeter did not transfer heart rate readings to an app or website, or other media.

The Apple Strava App was selected for its ability to continuously record heart rate during an activity and then copy that recording to a paired iPhone, which then uploaded the data of the recorded heart rates to an account on the Strava website. A passworded account administered by the researcher was used to store data recorded using the Strava App.

Below is an example of a record of a continuous heart rate recording over 2 minutes and 32 seconds recorded on 10 September 2018. The range of heart rate values, 63-74, is depicted to the left of the graph, seen in Figure L13.

Figure L13 - *Continuous Heart Rate Recorded on Apple Watch, Series 3 using Strava app.*

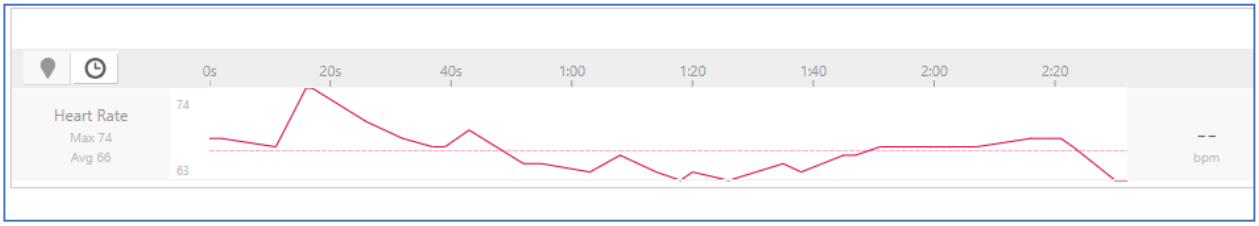
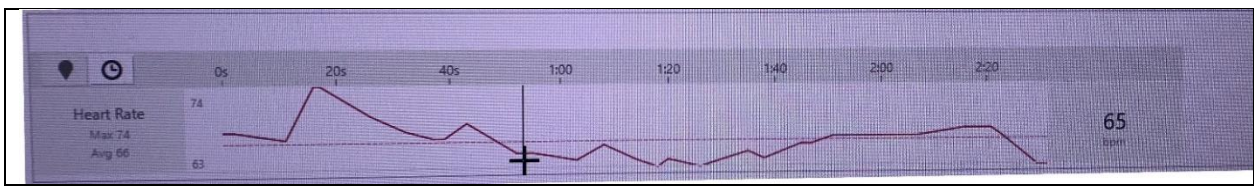


Figure L14 reproduces a graph of a continuous heart rate recording, illustrating that a specific heart rate value can be obtained for any 5-second interval. A camera photograph instead of a computer screenshot was taken because the mouse marker disappeared when moved.

Figure L14 - *Recorded heart rate (65 bpm) dynamically from a Strava recording.*



Appendix M - Cycling - Procedure – Riding in Natural, Mixed & Virtual Realities

(1) Expresso Bike in Manual Mode (Natural Reality)
(2) Expresso Bike in Dragon Chase Game (Mixed Reality)
(3) VirZOOM Bike in Manual Mode (Natural Reality)
(4) VirZOOM Bike in Thunder Bowl Tank Chase Game (Virtual Reality)

Both the Expresso Dragon and the VirZOOM tank chase games allow the participant to ride at a preferred pace without penalty. Points are not lost for slowness or cessation of pedaling. Participants need not experience physical exhaustion.

One participant, comparing manual and Virtual Reality (VR) modes, observed that "VR is way more enjoyable because you're concentrating more on the game than on riding."

The same game was not available on the two bikes; the games on the bikes were proprietary, and each was not available on the other bike. There was a single game available for the Expresso Bike: the "Dragon Chase Game. There were eight different games on the VirZOOM bike:

1. Keep Flying – fly astride a Pegasus, hunt for treasure, or race around the canyon.
2. Race Car – Drive a car in races on two different race tracks.
3. Jailbreak! – Chase and capture bandits by whirling a lasso while riding a horse.
4. Thunder Bowl – Head-to-head tank and mech battles in the sand or the snow.
5. Lotus Pond – Gently steer a kayak while feeding ducks and collecting gems.
6. Le Tour – Bicycle racing through the countryside while drafting other riders.

It was important to select a game on the VirZOOM bike that is comparable in enjoyment to the Dragon Chase game on the Expresso bike so that enjoyment in the overall experience would be primarily attributable to differences in types of reality.

Table M22 - *Sensory Conflict Potential Criteria Chart*

Interactive Game	Representative Avatar: 1=yes, 0 = no	Point of View (POV): 1=1st Person 0=3rd Person	Movement: 2=Avatar 1=Vehicle 0=Teleportation or 3rd Person follow	Stabilizing Frame of Reference: 1=no, 0=yes	Total Sensory Conflict Potential
Games compared by Shafer et al. (2018):					
Minecraft	1	1	2	1	5
Elite: Dangerous	1	1	1	0	3
Lucky's Tale	0	0	0	1	1
Expresso Bike:					
Dragon Chase	0	1	1	0	2
VirZOOM Bike:					
Keep Flying	0	1	1	0	2
Racecar	0	1	1	0	2
Le Tour	0	1	1	0	2
Jailbreak!	0	1	1	0	2
Thunder Bowl	0	1	1	0	2
Lotus Pond	0	1	1	0	2

Shafer et al. (2018) summarized psychological criteria that contribute to variation in levels of sensory conflict when users engage with and react to videogames: spatial presence, perceived reality or realism, perceived interactivity, and enjoyment. (Tale M22.) Spatial presence is the feeling that one is located in the virtual world. Perceived reality is the perception that the virtual environment feels, looks, and sounds real. Perceived interactivity is the extent of mastery that a user feels that they have over the game. Enjoyment is the pleasure that a media user experiences because of being exposed to a certain media stimulus.

They created a chart used to compare three different interactive games: "Minecraft," "Elite: Dangerous," and "Lucky's Tale" (Shafer et al., 2018, p. 4). Table M23 extends that chart to compare the Expresso Dragon game and six VirZOOM games.

All VirZOOM games matched the sensory conflict potential criteria of the Expresso Dragon game. However, since enjoyment from Immersive Exergaming and not enjoyment from gaming is the object of this study, a further criterion was used to select the VirZOOM game most saliently similar to the Expresso Dragon Chase game and that was the propensity for a player to become physically exhausted. This circumstance diminishes the enjoyment of the overall experience.

Table M23 - *Expresso & VirZOOM Games' Structural Incentive to Pedal Rapidly*

Interactive Game	Incentive to Continue Pedaling to Achieve Game's Objective
Expresso Bike:	
Dragon Chase	Pedaling is strategic, with pace varying according to player's mood.
VirZOOM Bike:	
Keep Flying	Must continue pedaling to keep Pegasus in the air.
Race Car	Must pedal rapidly, or competitive virtual cars will pass the player.
Le Tour	Must pedal rapidly, or competitive virtual cyclists will pass the player.
Jailbreak!	Must pedal rapidly, or the jailbreaking cowboys will escape.
Thunder Bowl	Pedaling is strategic, with pace varying according to player's mood.
Lotus Pond	There is no penalty if not pedaling aside from opportunity cost.

Both the Expresso Bike's Dragon Chase game and the VirZOOM Bike's Thunder Bowl game require pedaling to propel the first-person vehicle in pursuit of targets. (See Table M19.) Only the VirZOOM Thunder Bowl game matched the Expresso Dragon Chase game in terms of strategic pedaling and, most importantly, for enjoyment among older adults, with a pace that varied according to player's mood, a pace that did not incur a perception of losing ground to opponents. For that reason, the VirZOOM Thunder Bowl game was chosen.

An Apple Watch Series 3 with a 42mm Nike Sport Wristband is worn on the left wrist. The 42mm Nike Sport Wristband was selected because it firmly accommodates a wide variety of wrist sizes. "Wristbands … need to be carefully placed and secured to ensure the most accurate

results." (Prospero, 2016) See Figure M15. A countdown timer allows the investigator to control time recording without disrupting the participant. See Figure M16.

Figure M15 - *Apple Watch Series 3 fastened with a black 44mm Nike Sports Wristband.*

Figure M16 - *Countdown Timer is used to time each ride.*

A disposable sanitary mask was used to provide a sanitation barrier between the helmet and the participant's face (Figure M17).

Figure M17 - *Disposable Sanitary Mask*

A sanitary wipe was used to clean the Apple Watch and bike handlebars following after each individual had completed their rides on each bike.

Group 1: Mixed Reality - Rides the Expresso Interactive Upright Bike**.**

The Expresso Interactive Bike S3U had a 19-inch screen. (Figure M18)

Figure M18 - *Expresso Interactive Upright Exercise Bike S3U*

5.7 Expresso Bike Pre-Trial Preliminary Protocol

- Turn on the power (1/0) switch, and then press the red reset button of the Expresso S3U Bike, found in the Control Panel located near the floor at the front of the Bike. (See figure M19.)

Figure M19 - *Power Switch in front of the Expresso S3U Bike*

- Place the Apple Watch on the participant's left hand so that it is snug without feeling uncomfortable. Enter the password on the Apple Watch.
- Adjust the bike seat's vertical and horizontal positions to the participant's preference.
- Show the participant how to adjust pedaling resistance by pressing gear buttons on the handlebars. (See figure M20.) Pressing the left gear button decreases resistance and increases speed. Pressing the right gear button increases resistance and reduces speed. Pressing either the side or front gear buttons works equally well.

Figure M20 - *The Expresso S3U Bike has gears on both sides of the handlebar.*

Ride the Expresso Bike in Manual Mode.

- Set the count-down timer to 5 minutes.
- Cover the screen with cardboard hung from the top of the monitor with scotch tape.
- Set the Expresso S3U Bike to “Manual Mode.”
- Select the “Indoor Ride” activity, Strava app, Apple Watch, by tapping the red circle icon adjacent to the name of the activity.
- Tap the start button on the count-down timer.
- Allow participants to ride the Expresso S3U Bike for 5 minutes.
- When the count-down timer buzzes, state in a calm voice, “Stop, please stop.”
- Select the “Indoor Ride” activity, Strava app, Apple Watch, swipe right, press the “Finish” icon, and press the red “Save” icon.

Ride the Expresso Bike While Playing the Dragon Chase Game.

- The Dragon Game home screen (Figure M21) depicts objects and rules for playing the game. While the participant views the cover screen, describe how to play the Dragon Chase Game.
- During a Friendly Pilot in September 2018, preliminary instructions using Figure M21 were found to be sufficient for full subject participation without rehearsal practice.

Figure M21 - *Home Screen of the Expresso Bike Dragon Game depicting game objects.*

Rules of the Expresso Bike Dragon Game:

- Pressing the left gear button decreases resistance and increases speed.
- Riding down a hill decreases resistance and increases speed.

<><><><><><><>

- Pressing the right gear button increases resistance and decreases speed.
- Riding up a hill increases resistance and decreases speed.

<><><><><><><>

- Double or quadruple score by running over an orange "Score Power Up" lamp.
- Double or quadruple speed by running over a "Speed Power Up" lamp.
- Temporarily daze the sought dragon by running over a "Dazed Dragons" object.

<><><><><><><>

- Step 1: Steer the chariot over a colored coin.
- Step 2: Follow the yellow arrow. It points to the matching colored dragon.

  Points are awarded according to the dragon's color: 100, 300, 500, 1000.

- Step 3: Drive the chariot through a dragon whose color matches the coin.
- Repeat steps 1 through 3.

- Select the *Strava* app on the Apple watch. Select the "*Indoor Ride*" activity.
- Set the count-down timer for 5 minutes.
- Select the Dragon Chase Game on the Expresso S3U Bike.
- Go to the cover page of the Dragon Chase Game. (See cover page in Figure M12.)
- Explain the rules of the Dragon Chase Game to the participant.
- Press the "OK" button. A new screen shows a selection for "5 minutes".

- Select the “Indoor Ride” activity, Strava app, Apple Watch, by tapping the red circle icon adjacent to the name of the activity.
- Press “OK” on the Game screen. The game begins.
- Tap the start button on the count-down timer to anticipate when 5 minutes expire.
- Allow participant to ride until the game automatically terminates after 5 minutes.
- Approach the participant when the game stops after 5 minutes.
- Select the “Indoor Ride” activity, Strava app, Apple Watch, swipe right, press the “Finish” icon, and press the red “Save” icon.

Group 2: VirZOOM Bike (Virtual Reality)

VirZOOM Bike Pre-Trial Preliminary Protocol:

This procedure prepares the VirZOOM Bike (Figure M22) to run under Windows Mixed Reality when wearing a Samsung Galaxy Odyssey helmet (Figure M23). Hand controllers are not used.

Figure M22 - *VirZOOM Bike.*

Figure M23 - *Samsung Odyssey Helmet is worn when riding the VirZOOM Bike*

- Adjust the bike seat's vertical and horizontal positions to the participant's preference.
- Turn on the PC computer. Launch Windows Mixed Reality platform.
- Ensure that the Mixed Reality boundary has been set. The boundary looks like a white outline inside mixed reality and appears when you come close to it. It is not needed for safety while riding a VirZOOM bike, but the image in the helmet will not be mirrored to an external monitor if the boundary has been set.
- If the helmet display does not mirror an external screen, press the "Play" triangle.
- Ensure that music is turned off. Do not use options for various music stations.
- Select learning to steer left and right. A steering option by tilting the head will not be used.
- Ensure that the VirZOOM bike Bluetooth USB dongle is inserted into a USB port on the computer. (The VirZOOM bike wirelessly transfers data between the PC and headset via Bluetooth communication.)
- Flick the VirZOOM Bike switch to the on position.
- Show the participant how to calibrate resistance by turning a black knob under the handlebars on the bike.
- Place the Apple Watch on the participant's left hand so that it is snug without feeling uncomfortable. Enter your password on the Apple Watch.
- Set the count-down timer to 5 minutes.

5.7.1.1 VirZOOM Bike in Manual Mode

- Have the participant sit on the VirZOOM Bike seat.
- Instruct and assist the participant in placing the HMD comfortably on their head.
  - Demonstrate that HMD can be tightened or loosened by adjusting the back button.
  - Demonstrate the bottom HMD button to adjust the pupil distance between eye lenses.

  - Demonstrate that the front of the HMD can be pulled forward to adjust comfort.
- Verify that image in HMD is mirrored to an external monitor or television screen.
- Rehearsal: Acquaint participant with how to steer the tank, aim, and shoot.
  - Use your head to aim the barrel of the tank. Look in 360-degree directions.
  - When the target circle is red, you cannot strike an enemy tank.
  - Then the target circle is green; you can strike an enemy tank by releasing a shell.
  - Release a tank shell by pressing the right trigger on the handlebar.
  - Pedal to move forward.
  - Lean left to steer left. Lean right to steer right.
- Begin monitoring the participant's heart rate. Select the "Indoor Ride" activity, Strava app, Apple Watch, by tapping the red circle icon adjacent to the name of the activity.
- Tap the start button on the count-down timer.
- Allow the participant to ride the VirZOOM Bike for 5 minutes.
- When the count-down timer buzzes, state in a calm voice, "Stop, please stop."
- Stop monitoring heart rate. Select the "Indoor Ride" activity, Strava app, Apple Watch, swipe right, press the "Finish" icon, and press the red "Save" icon.
- Ask the participant to disembark from the VirZOOM Bike.
- Ask the participant to sit in a seat.
- Administer the Joy & Cleveland questionnaires.

Appendix N – Cycling - Two-Way Mixed Analysis of Variance (ANOVA)

This appendix was created in 2020 for an early draft of the Interactive Bike Study.

Two-way Mixed ANOVA is "two-way" because there is a within-subjects comparison and a between-subjects comparison. (See Table N24.)

Independent ANOVA

One independent variable is analyzed "between conditions," with participants taking part in only one of two different conditions. In the Bike Study, participants ride either the VirZOOM bike or the Expresso bike but not both bikes.

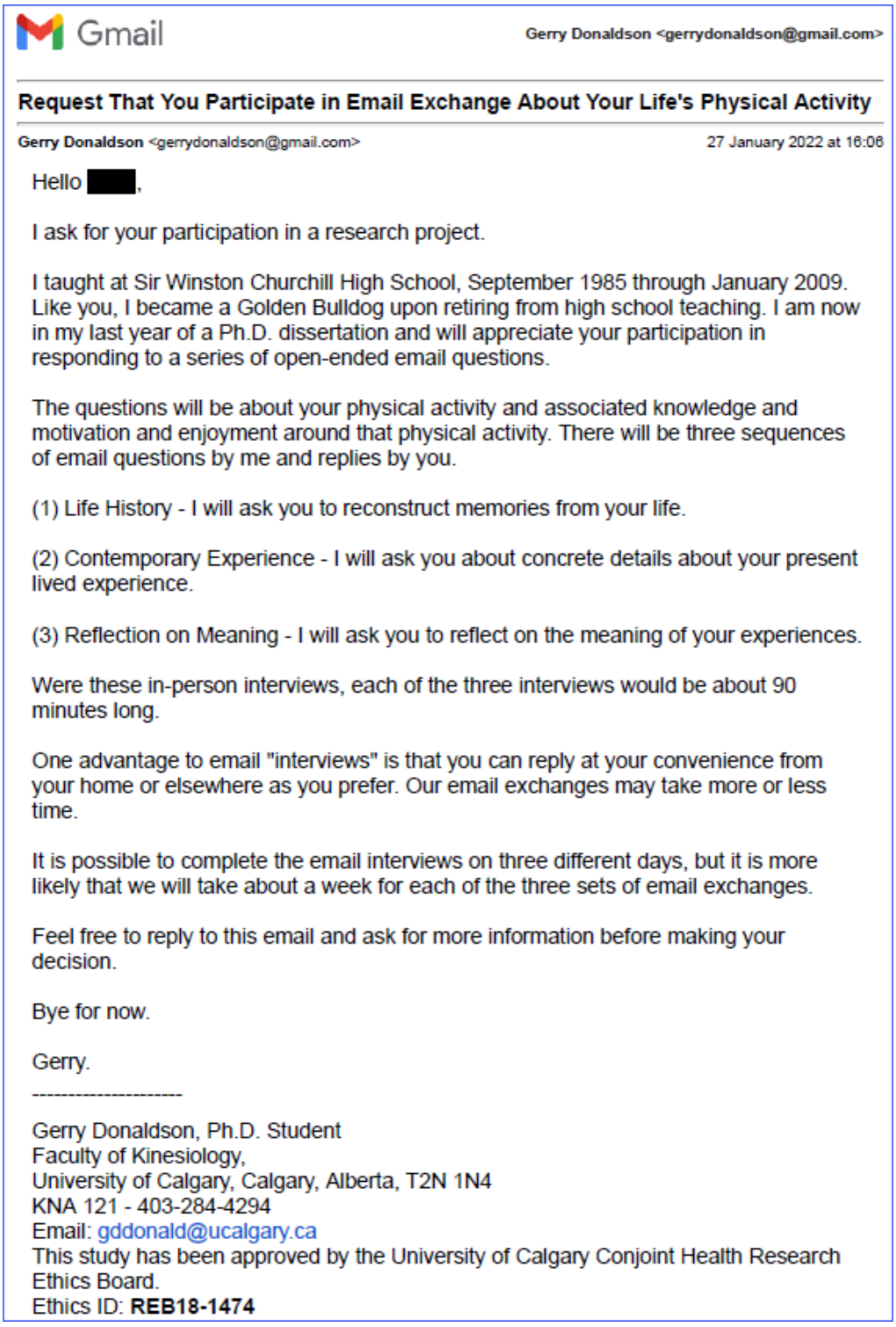
Repeated Measures ANOVA

The other independent variable is analyzed "within conditions," with participants taking part in two levels of "reality." In the Bike Study, participants first ride in Natural Reality (NR) with no interactive exergaming while riding; then secondly, participants ride in one of two different types of Extended Reality (XR), playing an interactive exergame while riding.

Table N24 – *Two-Way Mixed ANOVA - Bike Study*

<table>
<tr><td></td><td colspan="4">Type of Independent Variable</td></tr>
<tr><td rowspan="2">Type of ANOVA</td><td colspan="2">Independent ANOVA</td><td colspan="2">Repeated Measures ANOVA</td></tr>
<tr><td colspan="2">Between Conditions
(Between Levels)</td><td colspan="2">Within Conditions
(Within Levels)</td></tr>
<tr><td>Degree of Participation</td><td colspan="2">Participants take part in only one of two conditions:
(1) Ride the Express Bike or
(2) Ride the VirZOOM Bike</td><td colspan="2">Participants take part in both environments:
(1) Natural Reality (NR) and
(2) Extended Reality (XR)</td></tr>
<tr><td>Independent Variable Description</td><td colspan="2">Type of Bike</td><td colspan="2">Type of Environment</td></tr>
<tr><td rowspan="3">Conditions (Levels) of Independent Variable</td><td rowspan="3">VirZOOM Bike
(1)</td><td rowspan="3">Expresso Bike
(2)</td><td rowspan="3">Natural Reality (NR)
No Exergaming
No Technology</td><td colspan="2">Extended Reality (XR)
Yes Exergaming</td></tr>
<tr><td colspan="2">Types of XR</td></tr>
<tr><td>Mixed
(MR)</td><td>Virtual
(VR)</td></tr>
</table>

Appendix O – Delphi - Email to Recruit Panelists



Gmail — Gerry Donaldson <gerrydonaldson@gmail.com>

Request That You Participate in Email Exchange About Your Life's Physical Activity

Gerry Donaldson <gerrydonaldson@gmail.com> 27 January 2022 at 16:06

Hello [redacted],

I ask for your participation in a research project.

I taught at Sir Winston Churchill High School, September 1985 through January 2009. Like you, I became a Golden Bulldog upon retiring from high school teaching. I am now in my last year of a Ph.D. dissertation and will appreciate your participation in responding to a series of open-ended email questions.

The questions will be about your physical activity and associated knowledge and motivation and enjoyment around that physical activity. There will be three sequences of email questions by me and replies by you.

(1) Life History - I will ask you to reconstruct memories from your life.

(2) Contemporary Experience - I will ask you about concrete details about your present lived experience.

(3) Reflection on Meaning - I will ask you to reflect on the meaning of your experiences.

Were these in-person interviews, each of the three interviews would be about 90 minutes long.

One advantage to email "interviews" is that you can reply at your convenience from your home or elsewhere as you prefer. Our email exchanges may take more or less time.

It is possible to complete the email interviews on three different days, but it is more likely that we will take about a week for each of the three sets of email exchanges.

Feel free to reply to this email and ask for more information before making your decision.

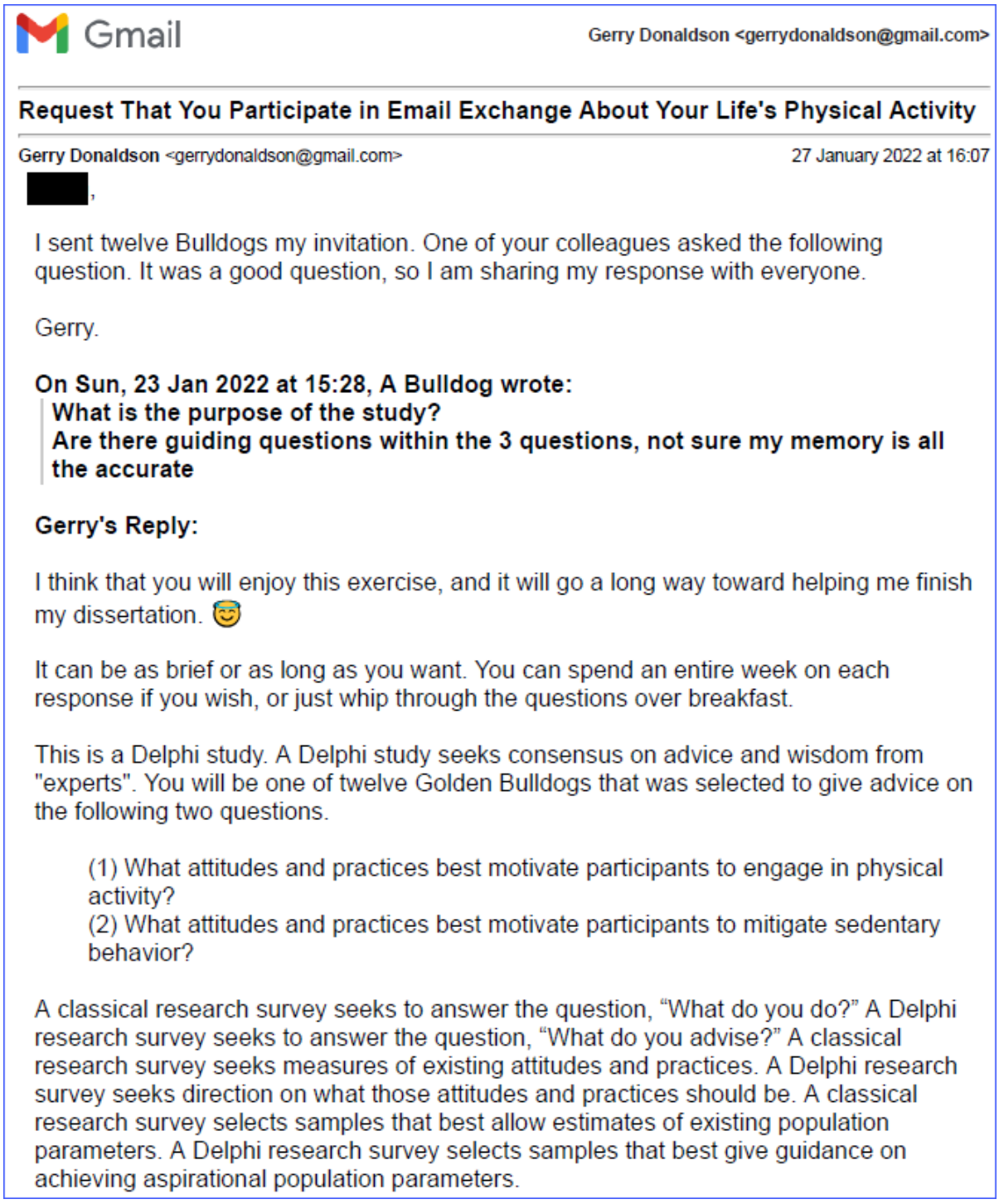
Bye for now.

Gerry.

Gerry Donaldson, Ph.D. Student
Faculty of Kinesiology,
University of Calgary, Calgary, Alberta, T2N 1N4
KNA 121 - 403-284-4294
Email: gddonald@ucalgary.ca
This study has been approved by the University of Calgary Conjoint Health Research Ethics Board.
Ethics ID: **REB18-1474**

Appendix P – Delphi - Reply Email Giving Details on Expectations

Delphi Reply Email on expectations Page 1



Gmail — Gerry Donaldson <gerrydonaldson@gmail.com>

Request That You Participate in Email Exchange About Your Life's Physical Activity

Gerry Donaldson <gerrydonaldson@gmail.com> 27 January 2022 at 16:07

[redacted],

I sent twelve Bulldogs my invitation. One of your colleagues asked the following question. It was a good question, so I am sharing my response with everyone.

Gerry.

On Sun, 23 Jan 2022 at 15:28, A Bulldog wrote:

> **What is the purpose of the study?**
> **Are there guiding questions within the 3 questions, not sure my memory is all the accurate**

Gerry's Reply:

I think that you will enjoy this exercise, and it will go a long way toward helping me finish my dissertation. 😇

It can be as brief or as long as you want. You can spend an entire week on each response if you wish, or just whip through the questions over breakfast.

This is a Delphi study. A Delphi study seeks consensus on advice and wisdom from "experts". You will be one of twelve Golden Bulldogs that was selected to give advice on the following two questions.

(1) What attitudes and practices best motivate participants to engage in physical activity?
(2) What attitudes and practices best motivate participants to mitigate sedentary behavior?

A classical research survey seeks to answer the question, "What do you do?" A Delphi research survey seeks to answer the question, "What do you advise?" A classical research survey seeks measures of existing attitudes and practices. A Delphi research survey seeks direction on what those attitudes and practices should be. A classical research survey selects samples that best allow estimates of existing population parameters. A Delphi research survey selects samples that best give guidance on achieving aspirational population parameters.

Delphi Reply Email on expectations Page 2

A Delphi method is a method for obtaining a "consensus" of wisdom and advice from a panel of "experts."Anonymity is assured so that members of the panel will not feel inhibited in responding. Anonymity also inhibits formation of a "herd response" to the questions.

You were chosen as one of twelve Golden Bulldog panelists for this survey because you served the longest in your department according to the Golden Bulldog Members List distributed on January 9, 2022.

The operational assumption, which I support, is that members of the Golden Bulldog community are experts on living by virtue of the career they experienced. My dissertation is about physical activity and sedentary behavior, so I will ask questions about that. After teaching in the SWC community for so many years, I am convinced that a community like the Golden Bulldogs has valuable wisdom to share.

Anonymity is assured so that members of the panel will not feel inhibited in responding. Anonymity also inhibits the formation of a "herd response" to questions.

There will be three emails that you will be asked to respond to.

Round 1: Open-ended Questions - The first email will ask open-ended "brain-storming" questions to establish the context of enjoyment for physical activity and sedentary behavior in one's life.

I will then review the twelve Bulldogs responses and prepare multiple-choice questions based on those responses. There will be no "right or wrong" answers to the multiple-choice questions.

Round 2: Structured Questions and Justifications - The second email will ask you to answer the multiple-choice questions and state justifications for your responses. The multiple-choice questions will be based on responses to the first email.

I will then analyze Round 2 responses and create summaries of those responses. I will then send all twelve members of our panel of experts summaries of how everyone responded to the Round 2 questions.

Round 3: Consensus Formation - An analysis from responses to the Round 2 questionnaire responses is fed back to the participants so everyone knows **anonymously** how the others responded. I assure anonymity. In Round 3 participants are asked to answer questions after considering the Round 2 responses of the other 11 panelists.

I will distribute this response to all twelve of our anonymous Bulldogs because it was such a great question.

Thanks much.

Gerry.

Appendix Q – Delphi - Letter of Consent

UNIVERSITY OF CALGARY

CONSENT FORM

TITLE: A Study of The Motivation of Enjoyment on Physical Literacy of Older Adults.

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 for your records.

INVESTIGATORS:

Larry Katz, Ph.D., Professor (Principal Investigator)
University of Calgary - Faculty of Kinesiology
403-220-3418

Gerry Donaldson, Ph.D. Student
University of Calgary - Faculty of Kinesiology
403-284-4294

BACKGROUND

To maintain a healthy lifestyle, it is important to be physically active. We are more likely to remain physically active if we enjoy doing physical activity. An active lifestyle helps us stay healthy, be comfortable and be motivated to continue being physically active.

A convenience sample of older adults will be selected and asked about their attitudes toward Physical Literacy and factors that motivate them to engage in and refrain from physical activities.

Individuals will be interviewed and electronically by email.

WHAT IS THE PURPOSE OF THE STUDY?

You are being asked to participate in a research study entitled: ***A Study of The Motivation of Enjoyment on Physical Literacy of Older Adults.*** The purpose of this research study is to investigate factors that contribute to or detract from the enjoyment of older adults while engaged in physical activity.

WHAT WOULD I HAVE TO DO?

You will be asked both short answer and long-form questions. You do not have to answer any question that makes you uncomfortable for any reason.

A questionnaire posing demographic questions will take about fifteen minutes to answer.

Time taken to Respond to open-ended questions posed by email is determined by the amount of detail given by you, the participant, but may vary from minutes to an hour per exchange.

The online survey should take less than 30 minutes.

You will be asked demographic questions about your gender, height, weight, birth date, education, income and expenses.

You will be asked leading questions about your life's experiences with physical activity in terms of the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engaging in physical activities for life.

You will be asked both brief and leading questions about experiences that inspired the enjoyment of physical activity and experiences that inspired discontent or dissatisfaction of physical activity.

All email, Skype and online interaction will be electronically recorded and retained.

WHAT ARE THE RISKS?

Discomfort from participation with the email interviews should be absent or minimal since you may respond at your own pace.

WILL I BENEFIT IF I TAKE PART?

There is no immediate benefit to the participant. In appreciation of your support for this study, you will be emailed the results of this study when it is completed.

DO I HAVE TO PARTICIPATE?

Your participation in this research study is completely voluntary. You may stop at any time for any reason. Just let the investigator know. The investigator can withdraw you at any time for any reason.

WHAT ELSE DOES MY PARTICIPATION INVOLVE?

In this research, personal information will be collected; including name, gender, age and experience. However, names will not be connected to the data for analysis and presentation of results.

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?

There is no cost associated with participation in this study; there is also no remuneration.

CAN DATA COLLECTED ON PARTICIPANTS BE WITHDRAWN?

Data can only be withdrawn up until the point that your study team begins analyzing the data.

WILL MY RECORDS BE KEPT PRIVATE?

All participants will receive a randomized number that will be the only connection to the collected information. The name of each participant and their corresponding code shall be locked in a separate secure cabinet from the information collected during experiment. All field notes, journals, videos or observations shall remain in the co-investigator's possession or securely locked in a filing cabinet inside the co-investigators office.

Final results will be shared publicly in the University of Calgary for academic proposes. It is also intended that the results will be presented at conferences and through written publications. A description of this study will be available on http://www.ridevirtual.org/. The web site will include a summary of the results. You may search this web site at any time.

Data collected from your participation in this research study will be de-identified and will be held in a database for future use by other researchers. Any future use of this research data is required to undergo review by a Research Ethics Board.

AGREEMENT TO PARTICIPATE

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 their participation as a subject. 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 penalty. If you have further questions concerning matters related to this research, please contact:

Gerry Donaldson, PhD Student, University of Calgary, 403-284-4294, gerrydonaldson@gmail.com.
Larry Katz, PhD, Professor (Supervisor), University of Calgary, 403 220-3418 katz@ucalgary.ca.

If you have any questions concerning your rights as a possible participant in this research, please contact The Chair of the Conjoint Health Research Ethics Board, University of Calgary at 403-220-7990.

Participant's Name	Signature and Date
Investigator/Delegate's Name	Signature and Date
Witness' Name	Signature and Date

The investigator or a member of the research team will, as appropriate, explain to you the research and your involvement. They will seek your ongoing cooperation throughout the study. 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 R – Co-author Letter of Permission from Dr. Larry Katz

UNIVERSITY OF CALGARY

Sport Technology Research Laboratory
FACULTY OF KINESIOLOGY
2500 University Drive NW
Calgary, AB, Canada T2N 1N4

June 4, 2022

Re: Permission to reproduce papers in your Dissertation that include me as author.

Dear Gerry:

For those documents that include my name (see below), I give you permission to include the documents in your dissertation.

Donaldson, G. D., Sheehan, D. P., & **Katz, L.** (2022). Physical Literacy Vindicated: The Mind Is the Function of a Body Embedded Brain. *Advances in Physical Education*, 12(02), 142-160. https://doi.org/10.4236/ape.2022.122011.

Donaldson, G. D., Sheehan, D. P., Boyd, J., & **Katz, L.** (2022*). Older Adult Enjoyment, Perceived Effort, and Actual Effort While Riding Interactive Stationary Bikes in Different Virtual Levels of Chase-Based Exergaming Interfaces*. Faculty of Kinesiology. University of Calgary.

Donaldson, G. D., Sheehan, D. P., & **Katz, L.** (2022). *Optimize Physical Activity & Mitigate Sedentary Behavior for Life: An Electronic Delphi Study - Retired Teachers Advise Adolescents*. Faculty of Kinesiology. University of Calgary.

Sincerely,

[redacted]

Larry Katz, PhD
Professor Emeritus
Adjunct Professor and Director
Sport Technology Research Lab

Appendix S – Co-author Letter of Permission from Dr. Dwayne Sheehan

Dwayne Sheehan [redacted] 7 June 2022 at 11:42
To: Gerry Donaldson [redacted]

Dear Gerry:
For those documents that include my name (see below), I give you permission to include the documents in your dissertation.

Donaldson, G. D., Sheehan, D. P., & Katz, L. (2022). Physical Literacy Vindicated: The Mind Is the Function of a Body Embedded Brain. Advances in Physical Education, 12(02), 142-160. https://doi.org/10.4236/ape.2022.122011.
Donaldson, G. D., Sheehan, D. P., Boyd, J., & Katz, L. (2022). Older Adult Enjoyment, Perceived Effort, and Actual Effort While Riding Interactive Stationary Bikes in Different Virtual Levels of Chase-Based Exergaming Interfaces. Faculty of Kinesiology. University of Calgary. Donaldson, G. D., Sheehan, D. P., & Katz, L. (2022). Optimize Physical Activity & Mitigate Sedentary Behavior for Life: An Electronic Delphi Study - Retired Teachers Advise Adolescents. Faculty of Kinesiology. University of Calgary. Sincerely,

Be well,

Dwayne Sheehan, PhD
Associate Professor of Health and Physical Education
Faculty of Health, Community and Education
Mount Royal University
Calgary, Canada
[redacted]

"Learn it through play and it's there to stay" Anne Innskeep, 1926

Appendix T – Co-author Letter of Permission from Dr. Jeffrey Boyd

Date: 6 June 2022

From: Jeffrey E. Boyd
Department of Computer Science
University of Calgary

To: Gerry Donaldson

Subject: Permission to use co-authored manuscripts in PhD dissertation

Dear Gerry:

I grant you permission to use the following manuscript that I co-authored with you in your PhD thesis dissertation:

> Donaldson, G. D., Sheehan, D. P., Boyd, J., & Katz, L. (2022). Older Adult Enjoyment, Perceived Effort, and Actual Effort While Riding Interactive Stationary Bikes in Different Virtual Levels of Chase-Based Exergaming Interfaces. Faculty of Kinesiology. University of Calgary.

Yours Sincerely

Jeffrey Boyd

References – Appendices

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