EXERGAMING ACCEPTANCE AND EXPERIENCE IN HEALTHY OLDER PEOPLE AND OLDER PEOPLE WITH CHRONIC MUSCULOSKELETAL PAIN

by

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I declare that this thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due acknowledgement is made in the text of the thesis.

ABSTRACT

The research reported in the thesis investigated exergaming acceptance and experience in older people with special reference to technology acceptance, flow state, chronic pain and balance control. In recent years, there has been an increasing amount of literature on the beneficial effects of exergaming on older people's health, well-being and balance, including the use of exergaming as a method of pain control. Nevertheless, when taken separately, specific studies vary in methodology and in type(s) of exergaming topics studied. Health benefits from exergaming may only be gained if older people take part in it. There is evidence in the literature to indicate that usage of a technology is preceded by user acceptance. Few studies, to date, have investigated how older people perceive and experience exergaming in relation to their perceived abilities and future intention to use it, from a technology acceptance point of view. Therefore, the purpose of this thesis was to see if (1) the exergaming technology was acceptable to healthy older people and older people with chronic pain and (2) it had any effect in the self-reported health status, pain conditions and balance in older people with chronic pain.

The current thesis consists of two separate studies. In Study 1, twenty-eight healthy older people participated in six 40-minute exergaming sessions within a three-week period. In Study 2, fifty-four older people with chronic musculoskeletal pain attended a twelve 40-minute exercise intervention within a six-week period, either randomised into an exergaming group (IREX^{TM} system) or standard physical exercises. A modified version of the Unified Theory of Acceptance and Use of Technology (UTAUT) was analysed at baseline and upon completion of the intervention, including specific time points throughout the study. Self-perceived chronic pain and flow state were analysed at baseline and after exercise intervention. Rate of perceived expended physical and mental effort was recorded after every exercise session and compared between groups. Heart rate was recorded in the second study. Postural sway was assessed at the start and the end of the intervention with Centre of Pressure data being extracted via a Kistler force plate (AP SD, AP range, ML SD, ML range and CoP velocity), where the conditions were quiet bipedal standing with eyes open and eyes closed.

Evidence from both studies showed that exergaming technology was acceptable to healthy older people and older people with chronic musculoskeletal pain. Recorded high levels of flow indicated the occurrence of flow during the intervention. Performance expectancy emerged as the strongest predictor of older people's behavioural in-

tention to use exergaming. Previous behaviour was an important influence of future behaviour, within the context of exergaming. In Study 1, there were significant increases throughout the intervention in most of the flow state variables except challenge-skill-balance, paradox of control and transformation of time. Thematic analysis of older people's responses relating to exergaming revealed that enjoyment was the most frequently cited theme. The significant increase of perceived physical exertion suggested that exergaming provided light-to-moderate intensity exercise for this cohort of healthy older people.

In Study 2, an interesting pattern emerged over time where earlier on in the intervention, effort expectancy significantly predicted older people's behavioural intention to use exergaming (instead of performance expectancy). This role was then taken over by performance expectancy mid-way through the intervention. This indicated that this sample of older people with chronic pain prioritised their personal ability to play the exergames, after which, they then considered the usability of the exergaming technology in choosing whether to use it in future, if it were readily made available. In addition, there was evidence of improvement in post-intervention pain intensity in the exergaming group, suggesting that exergaming may have alleviated older people's experience of pain to some extent. Flow levels significantly increased from the start to the end of the intervention. Significant improvements over time in postural sway parameters in the control and exergaming groups suggested that short-term exercise contributed to improved balance in older people with chronic musculoskeletal pain. The indication of improved postural sway due to significant medio-lateral reductions in the eyes-closed condition in the both groups suggested that older people with chronic pain could benefit from at least subtle improvements in balance after taking part in short-term exercise. Nevertheless, exergaming may have an effect on postural sway when visual sensory information is removed, as found in the experimental group that demonstrated a statistically significantly lower reduction of CoP excursion in the medio-lateral direction, than in the control group.

”Do as you say,
Say what you mean,
Be as you are,
No more, no less.”

– Sri Sathya Sai Baba –

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ABBREVIATIONS

α	alpha
ACSM	American College of Sports Medicine
AGS	American Geriatric Society
ANOVA	Analysis of variance
Ave	Average
β	Standardised regression coefficient
CI	Confidence interval
CoP	Centre of pressure
d	Cohen's effect size
DDR	Dance Dance Revolution
ε^2	Epsilon squared
η^2	Eta squared. Effect size measure used in repeated measures ANOVA
ES	Population effect size
F	F-ratio
f^2	Effect size measure used in multiple regression
FSS	Flow State Scale
GP	General practitioner
$h_p{}^2$	Partial eta squared
ICF	International Classification of Functioning, Disability and Health
ICT	Information and Communication Technology
IDT	Innovation Diffusion Theory
IREX^{TM}	Interactive Rehabilitation &Exercise System
IT	Information Technology
IS	Information Systems
κ	Fleiss' Kappa (a measure of interrater reliability for categorical variables)
LL	Lower limit
MAPS	Multidimensional Affect and Pain Survey
MCPU	Model of PC Utilization
MS	Mean square
MM	Motivation Model
NA	Not applicable
NS	Not significant
ρ	Pearson's correlation coefficient

R^2	Percentage of variance of the outcome variable that is accounted for by the predictors in a multiple linear regression analysis; effect size measure used in multiple regression; the coefficient of determination; the squared multiple correlation coefficient
SCT	Social Cognition Theory
SD	Standard Deviation
SMEQ	Subjective Mental Effort Questionnaire
SS	Sum of squares
t	t statistic
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UL	Upper limit
VIF	Variance inflation factor
VR	Virtual reality
WHODAS	World Health Organization Disability Assessment Schedule

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Chapter 1

Introduction

1.1 Background

Today, people are living longer than ever before, and the proportion of older people is growing. Older British people are increasing steadily in number and proportion of the total population, especially those aged 65 and older. Over the 25 year period (1985 to 2010), the median age of the UK population increased from 35.4 years to 39.7 years. By 2025, the ageing of the UK population is estimated to have risen to 42.2 years, an increase of 2.5 years in the quarter century after 2010. During the last century, there were peaks in the numbers of births after both world wars and a longer baby boom during the 1960s. Over the next 25 years people born just after World War II, now aged in their 60s, will continue into the oldest ages, reaching their late 80s by 2035. The 1960s 'baby boomers' currently in their mid 40s, will reach their early sixties around 2025, and by 2035 will be in their early 50s. As these birth cohorts age, they will contribute to the continuing ageing of the UK population (National Statistics Online, 2012).

In terms of increases in the number and proportion of older people, the percentage of persons aged 65 and over in the UK increased from 15% in 1985 to 17% in 2010, demonstrating an increase of 1.7 million people. By 2035, it is estimated that those aged 65 and over will account for 23 per cent of the total population. The fastest population increases are seen in the ‘oldest old’ (i.e. those aged 85 and above). Between 1985 and 2010 the percentage of the population aged 85 and over increased from 1 percent to 2 percent, with the number aged 85 and over more than doubling from nearly 0.7 million to reach over 1.4 million by 2010. By 2035, the number of people aged 85 and over is estimated to be almost 2.5 times larger than in 2010, reaching 3.5 million and accounting for 5 percent of the total UK population (National Statistics Online, 2012).

Nevertheless, the increase in the ageing population means that the overall number of people in our society with health or care needs will also rise.This brings implications for health and care services because older people, particularly those aged 85 and above, tend to experience health conditions or issues, and require more services than the younger old (Wolinsky et al., 1986; Peat et al., 2001). Older people experience health problems associated with disability and a reduced quality of life. One of these problems is chronic pain.

Chronic pain is defined as “pain that persists beyond normal tissue healing time, which is assumed to be three months” (Merskey and Bogduk, 1994). Difficult to treat and cannot always be resolved by available medical and physical treatments, chronic pain is a widespread problem affecting 18–57% of older people in developed countries (Blyth et al., 2001; Leveille et al., 2005; McCarthy et al., 2009). In the UK, chronic pain affects 7.8 million people at present (Donaldson, 2008). National UK statistics have indicated that about half of people aged over 65 years, and 56% of men and 65% of women aged 75 years and over, have reported experiencing chronic pain (RCP, 2007).

Chronic pain is a complex, subjective and personal experience. It is a significant problem for older people than for any other age group due to the high prevalence of musculoskeletal disorders and other medical conditions in this age group. Studies have estimated that 50% of older people living in the community have chronic pain, whereas 45–80% of older people living in care are affected with chronic pain (Ferrell, 1995; Elliott et al., 1999). Chronic pain in older people is more often experienced in major joints, the back, legs and feet, whereas visceral pain and headache are reported less often (Helme and Gibson, 2001).

The majority of older people who suffer from chronic pain experience declining sensory and motor functions, and have a particularly high risk of physical disability (Scudds and Robertson, 1998) and falling (Leveille et al., 2002). Falls and fall-related injuries, such as hip fractures, are a major problem among older people, often causing severe injuries, and loss of mobility and independence. For older people, regular physical activity helps maintain good health, functional ability and independence. Being physically active has the following benefits: reducing the risk of falling and bone fracture (Skelton and Beyer, 2003), improving physical stamina, muscle strength and functional ability, and helps in managing chronic pain and discomfort in joints associated with musculoskeletal conditions (e.g. arthritis) (Skelton et al., 1995; Chodzko-Zajko et al., 1998; Taylor et al., 2004). Regular exercise has also been reported to reduce symptoms of anxiety and depressive moods (Mather et al., 2002).

Adults aged over 65 years are recommended to perform moderately intense aerobic exercise 30 minutes daily, 5 days a week (Mazzeo and Tanaka, 2001; Haskell et al., 2007). Research has shown that exercise offers potential benefits in lessening the risk of falls by improving postural stability (Lord et al., 1996), muscle strength (Skelton et al., 1993; Skelton and McLaughlin, 1996) and flexibility (Rikli and Edwards, 1991; Province et al., 1995). Other health benefits include reducing the risk of cardiopulmonary problems, improving cardiovascular function (Miche et al., 2009) and psychological well-being (Yeung, 1996; Biddle and Faulkner, 2002; Mather et al., 2002). However, despite the known preventive and therapeutic benefits of exercise (Bean et al., 2004), a majority of older people do not perform enough exercise to derive any health benefit (Schutzer and Graves, 2004; Kruger et al., 2007). Older people who are reluctant to exercise have cited some of the following reasons: having pain in their joints (Hendry et al., 2006), fear of pain exacerbated by physical movement (Jones et al., 1987; Hendry et al., 2006), pain-related fear[1] (Somers et al., 2009), lack of interest (Crombie et al., 2004), fatigue (Cooper et al., 2001) and not feeling well (Schutzer and Graves, 2004).

Today, exergaming is the most popular alternative to conventional exercise with potential means to promote, motivate and encourage physical activity. Exergaming combines physical exercise with computer-simulated environments, featuring virtual-reality (VR) interactive games (e.g., the Wii Fit and Kinect for Xbox 360). Two examples of ex-

[1] refers to an excessive and debilitating fear of physical movement and activity resulting from a feeling of vulnerability to pain (Swinkels-Meewisse et al., 2003)

ergaming are cybercyling (i.e. riding a bicycle with VR simulated scenery) and Dance Dance Revolution (i.e. dancing on a dance pad).

Exergaming has been reported to make physical exercise more interesting and challenging, thus easing the usual perceptions of monotony, boredom and physical discomfort associated with traditional exercise (Holden and Dyar, 2002; Grealy et al., 1999; Chuang et al., 2005). While there are many forms and uses of exergaming (Rizzo et al., 2011), perhaps the most useful feature is that it can be customized or personalized according to a particular user's preferred level or ability (Rizzo, 2006; Göbel et al., 2010). This has led to the use of exergaming in rehabilitative interventions for people with disabling conditions such as stroke (Saposnik et al., 2010; Plow et al., 2011) and spinal cord injuries (Kizony et al., 2005).

Several attempts have been made to study the effects of exergaming in older people's physiological and psychological health states (van Schaik et al., 2008; Anderson-Hanley et al., 2012; Marston, 2010; Williams, Soiza, Jenkinson and Stewart, 2010; Wollersheim et al., 2010). Anderson-Hanley et al. (2012) reported greater cognitive function in older people who participated in cybercycling than in those who took part in traditional stationary cycling. In exergaming research using the Wii Fit, participants perceived enhanced feelings of physical, social and psychological well-being after playing Wii games (Wollersheim et al., 2010).

Researchers have also evidenced significant improvements using exergaming as a intervention for physical rehabilitation (Merians et al., 2002; You et al., 2005; Thornton et al., 2005). One such article which examined the effect of exergaming on balance and gait function in patients with chronic hemiparetic stroke reported that the experimental group had improved Berg Balance Scale scores, balance and ability to control weight shifting compared to the control group (Kim et al., 2009). Although much of exergaming research has been involved in investigating its physical and psychosocial effects in older people, there is some disparity in which not much is known about how older people perceive and experience exergaming, and whether or not exergaming is acceptable to them.

Furthermore, current literature is lacking in older people's experience of flow state while exergaming. Flow experience is important because it allows people to be completely absorbed in a particular activity (Csikszentmihalyi and Csikszentmihalyi, 1988; Csikszentmihalyi, 1990); and being in a state of flow, in turn, can influence people's likelihood of intending to continue to engage in that activity (Csikszentmihalyi et al., 1993). Within the context of this thesis, that activity for older people would be exergaming or exercising with computer technology. The experience of flow during exergaming could encourage older people's exercise participation in future, from which health benefits may be derived. The current thesis seeks to bridge the gap in the literature where older people's technology acceptance and flow experience are concerned.

To start with, the current thesis investigates technology acceptance and flow experience of exergaming in a sample of healthy older people in order to gain an insight into their exergaming experience. The influence of other acceptance variables on older people's future intention to engage in exergaming is further examined. By first understanding if this sample of healthy older people is receptive to the idea of exergaming, the investigation is then extended to another sample of older people, this time, those with self-reported chronic musculoskeletal pain.

Exergaming acceptance and flow experience in this sample of older people with chronic pain are important research topics. Chronic pain sufferers live with many of its adverse effects. These include depression (Parmelee et al., 1991; Bonnewyn et al., 2009), unwillingness or reluctance to exercise (Jones et al., 1987; Vlaeyen and Linton, 2000; Hendry et al., 2006), risk of falling (Leveille et al., 2002; Blyth et al., 2007) and balance impairments (Mientjes and Frank, 1999; Eggermont et al., 2012). If this sample of older people with chronic pain demonstrates willingness to use exergaming, this could have important clinical implications for the older population who are affected by chronic pain. For instance, exergaming would allow older people to be physically active, which is a characteristic of successful ageing (Leveille et al., 1999).

Once exergaming acceptance and flow experience are investigated in the sample of older people with self-reported chronic musculoskeletal pain, the current thesis subsequently investigates the effects of exergaming on self-reported health status, pain conditions, and balance in comparison to those of traditional exercise on self-reported health status, pain conditions and balance within this population. The research findings from the effects of exergaming on older people's self-reported health status, pain conditions and balance will offer several insights concerning exergaming as a worthwhile activity for older people.

1.2 Thesis Structure

This thesis is structured in a way that leads the reader through two separate studies. The first involves a sample of healthy older people while the second involves older people suffering chronic musculoskeletal pain. Both studies investigate exergaming acceptance and flow experience in older people, but the second also measures function, health status and balance of older people living with chronic pain as well as obtains estimates of pain prevalence and severity, which would be of further use to other researchers who wish to document health status and pain.

Chapter 2 discusses current literature surrounding technology acceptance, flow experience, exergaming, chronic pain, health status and balance in older people.

Chapter 3 reports the background, methods, results, and discusses the findings from a study with healthy older people. This study investigates exergaming acceptance and flow experience in older people who participate in a 3-week exergaming intervention.

Chapters 4 report the background, methods, results, and discusses the findings from a study with older people suffering from chronic musculoskeletal pain. In this study, the primary outcome measures are older people's exergaming acceptance and flow experience. The secondary outcome measures are older people's postural balance measurements and self-reported pain prevalence and intensity. This study also looks at older people's pain and health function and investigates postural balance during quiet bipedal standing in these older people who attended a 6-week intervention either by participating in exergaming or conventional exercise.

Chapter 5 discusses the overall findings of older people's exergaming experience and the effect of exergaming on self-reported health status, pain conditions and postural stability in older people with chronic musculoskeletal pain. Strengths, limitations and overall conclusions of the research are presented, along with recommendations for future research.

Chapter 2

Background and literature review

2.1 Introduction

This chapter discusses technology acceptance in older people, flow experience, chronic pain, and exergaming research involving older people. A review of current evidence relating to exergaming and the use of the Unified Theory of Acceptance and Use Technology (UTAUT) model in this research is presented. The chapter concludes with the aims of this thesis.

2.2 Technology acceptance in older people

Today technology pervades every aspect of people's lives, emphasising the need for technology adoption. With advancing age, people's needs generally revolve around the following domains: mobility, communication, health, living, housing and life activities such as voluntary or paid work and hobbies. Technology can offer opportunities for older people to facilitate their independence and to have a more productive and satisfying social and leisure life (Czaja et al., 2001; Havenith, 2001; Fozard, 2001). Examples of technological support are enhanced communication accomplished by mobile phones or email, rehabilitative support for declining capabilities such as electric wheelchairs, support for housework such as microwave ovens and food processors, and health technologies such as medical alert systems in case of emergency.

As technology gradually becomes an integral part of the lives of older adults, older people's views and attitudes on technology usage are becoming increasingly relevant topics of investigation. Although recent evidence suggests that older people are willing to use a wide range of technologies (Mitzner et al., 2010), a lower degree of technology adoption by older people compared to those under the age of 65 has also been reported (Docampo-Rama and van der Kaaden, 1998; Selwyn, 2004; Jones and Fox, 2009).

Numerous studies have attempted to explain older people's technology usage and attitudes (Eisma et al., 2003; Goodman et al., 2003*a*; Morris et al., 2007). Becker and van Goor (1997; 2001) suggested that technology generations were responsible for older people's choices of technological products where people who experience the availability of certain types of consumer products during their formative period (from childhood to the age of 25) were more likely to display similar technology usage many years later. Based on this concept, Docampo-Rama et al. (2001) argued that a key major generational divide exists between three groups of people: firstly, those who grew up socialised into mechanical styles[1] of interacting with consumer products (lasting up to the 1930s); secondly, those socialised into "electro-mechanical"[2] styles of interacting with consumer products (lasting up to the early 1980s, which they termed the electro-

[1]products such as keywound clocks.
[2]products such as semi-automatic washing machines.

mechanical (EM) generation); and thirdly, those who socialised into software style devices (termed the software (S) generation). They proposed that the current generation of older people (aged 70 and above) were slow to achieve familiarity with ICT technologies because of generation-related lack of earlier experience with such user-interfaces and age-related decline in ability (Docampo-Rama and van der Kaaden, 1998; Echt et al., 1998; Rogers et al., 1998).

Gilleard and Higgs (2008) described the digital divide as the distinction between people aged above 50 who used or did not use the Internet. They strongly argued that this digital divide was not defined by a technology generational division as contended by Docampo-Rama et al. (2001), but rather, was associated with a much broader generational divide *within* the older population, which they called the 'third age'. According to Gilleard and Higgs, using the Internet represented a significant lifestyle marker rather than a function of age-related differences in relation with income, education, employment and health status. People born nearer to the end of the first half of the twentieth century were more likely to use the Internet compared to those born closer to its beginning. This was true regardless of income, health status and whether the population was retired or still working. In short, internet usage among the current population of older people (aged 50 and above) in Europe and North America reflected a generational divide *within* that population. Other explanations why older people do not adopt technology comfortably and easily are a fear of technology or computer anxiety (Dyck and Smither, 1995; Laguna and Babcock, 1997), and little awareness of the potential benefits offered by technology (Czaja et al., 2001; Eisma et al., 2003; Dickinson et al., 2005).

On the other hand, there is no evidence to suggest that older people will not embrace new technologies if a particular technology addresses a need or interest of which is useful and beneficial to them (Goodman et al., 2003*b*; Selwyn, 2004; Demiris et al., 2005; Melenhorst et al., 2006). A good example is older people becoming the fastest growing consumer group of Internet users (Hart et al., 2008; Jones and Fox, 2009). Future technology adoption among older people may be increased if they are made aware of the benefits of technology through education and training programmes. Older people are more likely to accept a technology particularly if it is appropriately designed and introduced, and serves a purpose for them (Czaja et al., 2001; Eisma et al., 2003; Mitzner et al., 2010).

What we know about technology acceptance and use in older people is largely based upon studies that investigate the usability of information technologies among the elderly, such as pc use (Goodman et al., 2003*b*; Selwyn, 2004), Internet use (Morris et al., 2007), email (Melenhorst et al., 2006) and electronic banking (Matilla et al., 2003). To date, not much is known about older people's acceptance of technology for exercise. The current thesis seeks to gain that understanding by applying a technology acceptance model called the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) on older people's exergaming[3] experience.

[3] exercising using or with computers.

2.3 Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) was formulated and empirically validated by Venkatesh et al. (2003). It was developed as a technology assessment tool for managers in the field of Information Systems (IS) to gain a better understanding of factors influencing technology acceptance and to assess the likelihood of new technologies being accepted and used by users who may be less inclined to adopt and use new systems. According Bhattacherjee (2001), initial acceptance of IS by users is important because it affects the continued usage of the IS, which in turn, secures the success of an IS implementation. In other words, there must be a significant number of users who have already adopted and use the information systems regularly on a continued basis (Limayem et al., 2000; Bhattacherjee, 2001; Davis and Venkatesh, 2004; Cheung and Limayem, 2005) for its successful implementation. Therefore, in the field of IS, user acceptance research is particularly relevant in seeking answers to predict, explain and enhance user acceptance.

UTAUT integrates elements across eight models of technology acceptance, which use distinct sets of acceptance determinants and explain Information Technology (IT) acceptance in different areas. These models respectively, are the Theory of Reasoned Action (TRA) (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975), Technology Acceptance Model (TAM) (Davis, 1989; Davis et al., 1989; Venkatesh and Davis, 2000), Motivational Model (MM) (Davis et al., 1992; Venkatesh and Speier, 2000), Theory of Planned Behaviour (TPB) (Ajzen, 1991; Taylor and Todd, 1995*a*), Combined Technology Acceptance Model and Theory of Planned Behaviour Model (C-TAM-TPB) (Taylor and Todd, 1995*b*), Model of PC Utilization (MPCU) (Thompson et al., 1991), Innovation Diffusion Theory (IDT) (Rogers, 1995; Moore and Benbasat, 1991), and Social Cognitive Theory (SCT) (Compeau and Higgins, 1995*b*,*a*; Compeau et al., 1999). The UTAUT model is shown at Figure 2.1.

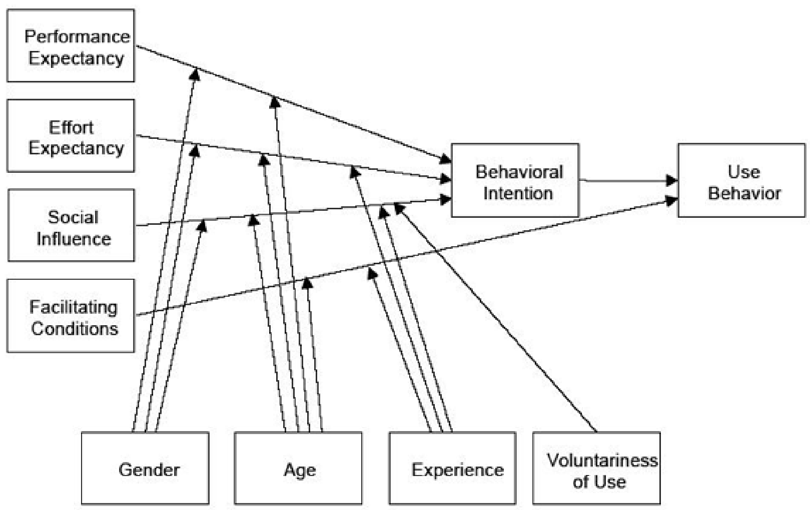

Figure 2.1: The UTAUT model (Venkatesh et al., 2003)

Venkatesh et al. (2003) tested the eight models against data from four organisations over a six-month period with three points of measurement. These models explained between 17 percent and 53 percent of the variance in users' intentions to use information technology. UTAUT was formulated with four core determinants of intention and usage (performance expectancy, effort expectancy, social influence, and facilitating conditions) and up to four moderators (gender, age, experience and voluntariness of use) of key relationships. The construct definitions of UTAUT are described in Table 2.1 on page 18. The unified model was also tested against the original data and found to be better than the eight technology acceptance models at predicting IT usage with an obtained adjusted R^2 of 69 percent. UTAUT was then confirmed against data from two new organisations, producing similar results (adjusted R^2 of 70 percent). This showed the high explanation ability of UTAUT in predicting IT usage.

UTAUT has been applied in a number of studies exploring users' acceptance of Informations and Communications Technology (ICT) use (Verhoeven et al., 2010), mobile technologies (Shin, 2009; Zhou et al., 2010), Web 2.0 technologies (e.g. wikis, blogs, social networking) (Baltaci-Goktalay and Ozdilek, 2010; Lin and Anol, 2008), digital learning environments (van Raaij and Schepers, 2008; Marchewka et al., 2007; Pynoo et al., 2011), health information systems (Chang et al., 2007; Kijsanayotin et al., 2009; Schaper and Pervan, 2007) and various IS applications (Curtis and Payne, 2008; Curtis et al., 2010; Schaupp et al., 2010).

Within the context of exergaming[4], the UTAUT model could be adapted to explore acceptance of this technology among older people. When we speak about technology and older people, it is not solely a matter of how technology can serve the older population, support ageing or facilitate daily tasks but also involves how older people feel about the technology and what they expect from it. In fact, there is a need to examine older people's needs, desires and aspirations and to incorporate these elements into technological innovations. It is clear that older people will not adopt a technology until it is deemed worthwhile or until technology has sufficiently evolved to address their needs and interests (Czaja et al., 2001; Eisma et al., 2003; Mitzner et al., 2010).

[4]exercising with computers or defined as a combination of exercise or physical activity with video games (Bogost, 2005)

It is important to investigate older people's behavioural intention[5] in using exergaming because once a behavioural intention to engage in regular exercise is formed, this means that the motivation phase[6] is completed during the exergaming experience and the person then enters a volitional stage[7], or voluntary phase, where they go ahead and do it. In other words, behavioural intention to use exergaming increases the likelihood that older people *will* perform exergaming. The current thesis investigated older people's behavioural intention to use the exergaming technology by modifying the UTAUT model (described in Chapter 3).

The technology acceptance measures applied in the current thesis originate from previous terminology of the Technology Acceptance model (Davis, 1989). For instance, performance expectancy (PE) was previously referred to as perceived usefulness (PU). This was a definition of "the degree to which a person believes that using a particular system would enhance his or her job performance technology acceptance models" (Davis, 1989; Davis et al., 1989). Effort expectancy (EE) was previously referred to as perceived ease of use (PEOU). PEOU was defined as "the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989; Davis et al., 1989).

[5]defined as "a person's subjective probability that he will perform some behaviour" (Fishbein and Ajzen, 1975)

[6]A person develops an intention to change or perform an action/behaviour, based on self-beliefs, such as risk perceptions, outcome expectancies, and perceived self-efficacy (Maslow, 1943).

[7]The intended behaviour must be planned, initiated and maintained, and relapses must be managed (Sniehotta et al., 2005).

Table 2.1: Definitions of Technology Acceptance measures

Measure	Definition	Reference
Performance expectancy (PE)	The degree to which a person believes that using a system will help them to attain gains in work performance. (In this research, refers to older people's perceptions that performing exergaming will help them to derive benefit from exercise.)	Davis (1989); Davis et al. (1989)
Effort expectancy (EE)	The degree of ease associated with the use of the system. (In this research, refers to older people's perceptions of how easy it is to exercise in an exergaming environment.)	Davis et al. (1989)
Social influence (SI)	The degree of which a person perceives that important others believe they should use the system. (In this research, refers to the social environment that influences older people to use exergaming).	Davis et al. (1989); Ajzen and Fishbein (1980); Fishbein and Ajzen (1975); Mathieson (1991); Taylor and Todd (1995*b*,*a*)
Facilitation conditions (FC)	The degree of which a person believes they are capable of using the system.	Davis et al. (1989)

(Continued on next page)

Table 2.1 – continued from the previous page

Measure	Definition	**Reference**
	(In this research, refers to older people's competency in using the exergaming system to perform exercise.)	
Self-efficacy (SE)	The degree of which a person is confident of using the system.	Ajzen and Fishbein (1980); Ajzen (1991)
	(In this research, refers to how confident older people are of using the exergaming system for exercise.)	
Behavioural intention (BI)	The degree to which a person has intention to use the system.	Fishbein and Ajzen (1975)
	(In this research, refers to older people's intention to use exergaming if it were readily made available.)	

2.4 Flow experience

Flow is one of the concepts within positive psychology, which is described as a transition from the conventional focus on assessing, curing and repairing psychological disorders to building positive qualities and improving aspects of human experience (Seligman and Csikszentmihalyi, 2000). Positive psychology seeks to understand subjective experiences such as well-being, contentment, satisfaction, optimism, flow and happiness in facilitating and leading a good life (Seligman and Csikszentmihalyi, 2000; Linley et al., 2006).

Flow experience is defined by Csikszentmihalyi (1975) as a state in which people become so involved in doing something, that nothing else seems to matter to them, and the result of this is an experience so enjoyable that people will even do it at great cost just for the sake of doing it. Flow is not only similar to peak experience and peak performance, but shares the same description of exuberance in peak experience and prolific behaviours associated with peak performance. Experiencing flow included either, or both (Csikszentmihalyi, 1975). In fact, measured flow is a degree of experience that defines the occurrence of flow in a particular activity (Novak et al., 2000).

Flow is also described as an optimal state in which the individual enjoys and is able to meet the demands and challenges required in that activity, loses awareness of the self, yet the individual is able to maintain control and concentration, and feels an intrinsic satisfaction at the end of that activity. For an individual experiencing flow, everything seems to be happening automatically (Csikszentmihalyi, 1975; Csikszentmihalyi and Csikszentmihalyi, 1988).

Flow comprises the following dimensions: clear goals and feedback, balance between challenges and skills, action and awareness merged, concentration on task, sense of potential control, loss of self-consciousness, altered sense of time and autotelic (self-rewarding) experience (Csikszentmihalyi, 1990, 1993). Clear goals refers to feelings of assurance or certainty where the individual has a distinctly defined objective, and feedback referred to the individual knowing in the instance, how well he is doing. Subsequent flow research by Jackson (Jackson, 1992, 1995, 1996; Jackson and Marsh, 1996; Jackson et al., 1998) showed that although clear goals and feedback were related with each other and usually discussed concurrently, they represented separate constructs. The term “unambiguous feedback” was used for feedback.

A balance between challenges and skills refers to a feeling of balance between meeting the demands of the situation and the skills required to cope with those demands. The merger between action and awareness refers to a sense of total immersion in the activity where the individual’s actions become automatic. Concentration on the task at hand is as per its namesake, the individual in full focus and concentration in the activity. A sense of potential control refers to the individual staying in control during the activity without conscious effort. A loss of self-consciousness refers to a sense of not concerned with oneself while engaging in the activity and in the process; the individual becomes one with the activity, or a part of it. The altered sense of time, later termed as transformation of time, refers to time being experienced as either passing more quickly, more slowly, or the individual may not be aware of the passing of time at all (Csikszentmihalyi, 1975; Csikszentmihalyi and Csikszentmihalyi, 1988).

Autotelic experience is described by Csikszentmihalyi (1990) as the end result of the flow experience; the individual has an enjoyable experience which is intrinsically rewarding, with no expectation of any reward or benefit other than or outside of the activity. In short, an enjoyable act of doing something for its own sake. While these flow dimensions are deemed to facilitate the conditions necessary for the occurrence of flow, together as a whole, they represent the flow experience (Jackson, 1996; Jackson and Marsh, 1996; Jackson et al., 1998; Jackson and Eklund, 2002). Table 2.2 presents the definitions of the flow variables.

Among athletes, flow is described as a highly valued and motivational experience by being “in the zone” (Young and Pain, 1999), “in the groove” or “tuned in” (Jackson, 1996). Web users describe the flow experience as being fully immersed in the Internet experience (Chen et al., 2000). The activities in which people experience flow may be very different, but how they describe their experience of being in flow is almost alike. A comprehensive list of flow definitions can be found in Novak et al. (1999).

Table 2.2: Definitions of flow variables

Flow variables	Definition	Reference
Autotelic experience (ENJY)	The optimal outcome of being in flow; an intrinsically rewarding experience doing a task solely for its own sake without expecting any reward or benefit.	Csikszentmihalyi and Csikszentmihalyi (1988); Csikszentmihalyi (1990); Jackson (1992, 1995)
Clear goals (GOAL)	When a person has a clearly defined focus of being confident of what they are going to do.	Csikszentmihalyi (1990)
Challenge-skill-balance (CHAL)	A feeling of balance is achieved when a person is able to skilfully cope with and manage the challenges and demands of a situation.	Csikszentmihalyi and Csikszentmihalyi (1988)
Concentration at task (CONC)	When a person is in full focus at the task.	Csikszentmihalyi (1990)
Paradox of control (CONT)	When a person feels that they are in absolute control of their actions without having to put in any conscious or exertive effort at the task.	Csikszentmihalyi (1993)

(Continued on next page)

Table 2.2 – continued from the previous page

Flow variables	Definition	Reference
Unambiguous feedback (FDBK)	Immediate, direct and clear observations felt by a person that they know how they are performing the task.	Csikszentmihalyi and Csikszentmihalyi (1988)
Action-awareness-merging (ACT)	When a person becomes fully immersed in the task, there is a feeling of automaticity of action until they lose awareness of the self.	Csikszentmihalyi (1990)
Transformation of time (TRAN)	Where time is experienced as either passing more quickly, slowing down, becoming irrelevant or out of one's awareness.	Csikszentmihalyi and Csikszentmihalyi (1988); Csikszentmihalyi (1990); Jackson (1992, 1995)
Loss of self-consciousness (LOSS)	In the event of full immersion in a task, a person retains an awareness of occurrences in mind or body but loses preoccupation with themselves.	Jackson and Marsh (1996); Csikszentmihalyi and Csikszentmihalyi (1988); Csikszentmihalyi (1990)

2.4.1 Purpose of flow experience

According to Csikszentmihalyi (1990), flow state leads to more positivity. When people are in the optimal state of flow, they are more likely to achieve more from the activity (or from what they were doing), learn new things and become better at what they are doing. People may also become more creative, and invent and discover new things. Thus, flow experience contributes to something else in the engaged activity. In addition, people absorbed in flow are likely to feel intrinsically rewarded and encouraged to persist in or go back to doing a particular activity. If people invest their attention and energy in pursuing a certain activity (e.g. hobby, work or sport), the skills or actions required for performing that activity may improve over time and increased repetitions of that particular activity.

Several studies have suggested that the concept of flow is useful in a variety of contexts. Examples are normal activities such as reading (McQuillan and Conde, 1996), recreational activities (Whitmore and Borrie, 2005), art (Csikszentmihalyi and Csikszentmihalyi, 1988), theatre (Martin and Cutler, 2002), music (Fritz and Avsec, 2007), consumer search, exploratory behaviour and online purchase behaviour (Webster et al., 1993; Novak et al., 2003; Hoffman and Novak, 2009).

Flow also plays a subtle role in an individual's intrinsic motivation. Hence it is suggested that people who perceive themselves to be more in control on their own actions are more likely to be intrinsically motivated (Deci and Ryan, 1985). In agreement with the emotional contagion theory (Hatfield et al., 1994), flow even has "crossover" qualities, where one person experiencing flow can influence another (Bakker, 2005). Given the vast applicability of flow, it is useful to understand the process of flow in order to learn how people may experience flow to their advantage.

2.4.2 Flow experience in older people

Flow has been measured, studied and portrayed in different ways. Studies investigating this phenomenon in older people have examined this within ageing and later life, or from a behavioural point of view (Voelkl, 1990; Collins et al., 2009; Lee, 2011; Hirao et al., 2012). Not much, however, exists in the literature about flow experience among older people, particularly in exergaming, which is generally known as exercising with or using computers. Exergaming is described in Section 2.9 on page 45. Perhaps the only recently published study in the current literature which includes the aspect of flow in older people's exergaming is that of Gerling, Schild and Masuch (2011), which investigated older people's exergaming experience by using the Nintendo Balance Board as an input device.

Gerling, Schild and Masuch (2011) compared the exergaming performance of older people who were either active or required extensive care and depended on assistive devices when walking. In this study, flow experience represented a minor aspect of game experience, using the Game Experience Questionnaire (GEQ) (IJsselsteijn et al., in press). The GEQ comprised seven different dimensions of player-experience: Sensory and Imaginative Immersion, Tension, Competence, Flow, Negative Affect, Positive Affect, and Challenge (IJsselsteijn et al., in press). Participants were invited to play SilverPromenade, a game which allowed players to go on virtual walks using the Nintendo Balance Board for game control. The GEQ was administered to the participants after the exergaming session. The exergaming experience was found to be positive due to the high scores for positive affect. Average values for flow, challenge and immersion were reported. The lowest scores were obtained for level of perceived competence.

Collins et al. (2009) investigated flow experiences in older people's daily and weekly activities. In their study, self-reports on how older people felt about their lives (i.e. life satisfaction) and daily activities were recorded. Higher quality of flow was found to be positively related to arousal positive affect (i.e. feeling happy, enthusiasm) and life satisfaction. Results also showed that flow was associated with affective experiences of older people, and suggested that an individual's overall propensity to experience flow could be influential beyond the immediate effects of a given flow experience (Collins et al., 2009).

Lee (2011) investigated how different types of serious leisure activity influence older people's flow experience. Results showed that older people experienced flow while performing leisure activities irrespective of the nature of the activities (i.e. physically, cognitively or socially-centred). The study concluded that the quality of flow experience had a significant impact on successful ageing among older people.

Hirao et al. (2012) investigated how flow was related to older people's quality of life. They found that older people who experienced flow were those who were the most physically healthy and were better at performing important daily activities. This was the same for older people who said they were more relaxed, compared to those who said they were apathetic when expressing satisfaction about their lives. Interestingly, they did not find any significant relationship between the degree of flow experience and stress. The authors concluded that older people could benefit from interventions that made daily life activities either high in both challenge and use of skills, or low challenge with high use of skills.

Payne et al. (2011) investigated how the relationship between flow experience and cognitive abilities in older people, particularly how motivational aspects of activity engagement affect cognitive outcomes in older people. In their study, participants aged between 60 and 94 years were asked to identify an enjoyable activity from the previous week and rate this activity representing the nine dimensions of flow state (Csikszentmihalyi, 1975). The activity was coded in terms of cognitive levels, whether they were high cognitive activities (e.g. working, reading, doing puzzles or challenging games) or low cognitive abilities (e.g. social events, physical exercise, watching television, cooking). Results showed that age was negatively related to fluid cognitive abilities (i.e. problem solving capability), but flow for both high-cognitive and low-cognitive activities was stable into very old age. Fluid capability influenced flow for demanding activities but was negatively related to flow for non-demanding activities. Older people were more likely to experience flow from cognitively demanding activities if they were high in fluid ability (Payne et al., 2011), showing that flow arises from an optimal balance between skill and challenge (Csikszentmihalyi, 1975).

As described above, most flow studies focus on healthy ageing or ageing-related activities and have expressed one thing in common: ageing does not diminish the capacity to experience flow (Payne et al., 2011). Very little is known about the flow phenomenon among older people especially during exercise or exergaming. This thesis seeks to add to the literature about older people's flow experience associated with exergaming.

2.5 Chronic pain in older people

Chronic pain is continuous pain that lasts more than 12 weeks or longer than the ordinary duration of time needed for an injury, illness or affliction to the body to recover. It can also be experienced by people who do not have evidence of tissue damage (Merskey and Bogduk, 1994). While acute pain acts as a part of the human body's protective mechanism, indicating potential tissue trauma or injury, chronic pain occurs as a result of central and peripheral sensitization in which pain is retained after the body gradually ceases to process nociceptive input. In other words, chronic pain does not serve any beneficial purpose (Burris, 2004).

In many world wide population-based studies, the prevalence of chronic pain was found to increase with age (Brattberg et al., 1996; Buskila et al., 2000; Helme and Gibson, 2001). Studies have indicated high prevalence of pain among elders living in communities (Helme and Gibson, 1999; Blyth et al., 2001) and in long-term care institution (Parmelee et al., 1991; Brochet et al., 1998) with estimates of 45–85% for the institutionalized elderly (Ferrell, 1995; Parmelee et al., 1991; Helme and Gibson, 2001). Other studies show that about 80% of older people suffer from a chronic disease frequently associated with pain (Fox et al., 1999; AGS Panel of Persistent Pain, 2002; Elliott et al., 2002). Studies have found that people in their middle years of age (i.e. age range of 50 to 59 years) experiencing chronic pain have a similar prevalence of functional limitation as people from the same population in the age range of 80 to 89 years who report no pain (Covinsky et al., 2009). This means that people with chronic pain develop the functional limitations classically associated with ageing at much earlier ages, indicating the potential impact of chronic pain on disability in later life (Scudds and Robertson, 1998; Covinsky et al., 2009).

In the UK, chronic pain affects 7.8 million people at present (Donaldson, 2008). National UK statistics have indicated that about half of people aged over 65 years, and 56% of men and 65% of women aged 75 years and over, have reported experiencing chronic pain (RCP, 2007). Elliott et al. (1999) investigated chronic pain prevalence in the Grampian region in northeast Scotland. They found that proportion of 3605 respondents (aged 25 and over) reporting chronic pain was 50.4%. Although there was no significant difference between men and women in this proportion (48.9 *vs* 51.8%), the proportion significantly increased with age from 31.7% for the youngest age-group to 62% for the oldest age-group. By standardising the sample to the age and sex distribution of the total population of patients registered with participating services, the prevalence of chronic pain in the general population was estimated at 46.5%.

Webb et al. (2003) carried out a prevalence study in neck and back pain in Tameside, Greater Manchester. From a total of 5752 respondents (stratified using age groups of 16 to 44 years, 45 to 64 years, 65 to 74 years, and 75 years or older), their findings showed that reported intense spinal pain[8] that had persisted for four weeks was 29% and half of that was chronic. The occurrence of intense, chronic spinal pain that was disabling was 20%. The peak prevalence for all reported back pain was 65 to 74 years in men and 45 to 64 years in women. Most people with back (75%) or neck (89%) pain also reported pain at other sites. The most common additional pain sites for those with neck pain were the shoulder, the back, and then the knee, and for those with back pain

[8]Spinal pain is defined as back or neck pain that has been present for the past one week or more in the last month (Webb et al., 2003).

were the knee, the shoulder, and then the neck. Age, female gender (neck pain only), high body mass index, living in an area of raised material deprivation, and south Asian ethnicity were significant predictors of spinal pain with disability.

Neuropathic pain related to peripheral neuropathy from diabetes mellitus, previous stroke, and post-herpetic neuralgia, as well as pain associated with peripheral vascular and cardiovascular diseases, skin ulcers, and cancer occur with greater frequency in older people (Burris, 2004). Older people also suffer chronic pain from having rheumatic diseases (Gibson and Clark, 1985) and orthopaedic conditions (Hen et al., 2008; Missaoui et al., 2008). For patients and their families, chronic pain results in increased costs for treatment, medication and insurance and decreased income before benefit can be claimed (Ferrell, 1996; Maniadakis and Gray, 2000).

Chronic pain is an extensively researched clinical subject. Despite immense efforts to investigate the causes, treatment and management of chronic pain, it is still undertreated, misdiagnosed or disregarded in the medical field. As a result, chronic pain sufferers, especially older people, tend to believe that chronic pain comes with ageing, and that they must endure it (Gagliese and Melzack, 1997; Sanders et al., 2002; Sofaer et al., 2005; Higgins, 2005).

2.6 Chronic musculoskeletal pain

Chronic musculoskeletal pain is the most predominant type of pain among community-dwelling older people (Brattberg et al., 1996; Grimby et al., 1999; Leveille et al., 2002;

Kamaleri et al., 2008; Woo et al., 2009; Brown et al., 2011). Musculoskeletal pain affects one in 4 adults and is the most common source of serious long-term pain and physical disability (Woolf and Åkesson, 2001; Walsh et al., 2008). Although there is a wide range of musculoskeletal conditions, they can be placed, respectively, within five major categories: (1) joint conditions (e.g. rheumatoid arthritis and osteoarthritis); (2) osteoporosis (e.g. fragility fractures); (3) spinal disorders (e.g. low back pain and neck pain); (4) musculoskeletal injuries (e.g. broken hip, limb fractures, strains, and sports-related sprains); and (5) childhood disorders (e.g. scoliosis, bow legs and knock knees).

In the UK, researchers have studied the prevalence of joint pain in older people in Calderdale, Yorkshire (Badley and Tennant, 1992), the Grampian region of Scotland (Elliott et al., 1999), the north of England (Croft et al., 1993), Glossop (Urwin et al., 1998), North Staffordshire (Thomas et al., 2004) and West Gloucestershire (Donald and Foy, 2004). The Calderdale study conducted a postal survey from 25,168 households, and found that 10,246 respondents (24% of the population, aged 16 years and older, of whom 6181 (60.3%) were women) reported pain, swelling or stiffness in the joints, neck or back. From a random sample of 5036 respondents, aged 25 and over, which included 346 people aged 75 years and above, the Grampian study estimated the prevalence of chronic pain in the general population as 46.5%. Among the oldest old, it was 62%. In a 4-year follow-up of this study, the overall prevalence of chronic pain increased from 45.5% at baseline to 53.8% at follow-up. The annual incidence of new-onset chronic pain was estimated at 8.3%, with annual recovery rate of 5.4%. This showed that chronic pain was persistent in most people, with 78.5% of individuals at baseline still reporting chronic pain after 4 years (Elliott et al., 2002).

The largest UK study involving people aged over 75 years is the Glossop study (Urwin et al., 1998), which included more than 1,100 respondents aged 75 and above. An estimated 63% of women and 49% of men reported joint pain in at least one site. The study conducted in West Gloucestershire recorded postal survey responses from 4,804 respondents aged 75 years and above (Donald and Foy, 2004). Their findings estimated some degree of joint pain at 83% from this population. A one-year follow-up of the study found an estimated 18% of acquired or increased frequency of pain, while there was a reduced frequency of pain at an estimated 14%.

Osteoarthritis and rheumatoid arthritis are the most common cause of chronic musculoskeletal pain (Breivik et al., 2006). Liu-Ambrose et al. (2002) found a high prevalence of back pain (75%) in 93 older women (aged between 65 and 75 years) with osteoporosis in British Columbia, Canada. Studies surveying chronic joint pain have found a more or less linear increase of pain with age until the age of 75 (Elliott et al., 1999; Donald and Foy, 2004; Ahacic and Kåreholt, 2010). Studies have also found evidence of decreased musculoskeletal pain among older people from the age of 85 (Brattberg et al., 1996). Although musculoskeletal pain is more commonly reported in older women (Brattberg et al., 1996; Brochet et al., 1998), pain severity is higher in older men aged 75 and above (Brochet et al., 1998).

The occurrence of chronic musculoskeletal pain is either widespread or localized. Localized musculoskeletal pain occurs in only one location while widespread pain is either defined as pain that has persisted for at least three months that is present in at least two contra-lateral body quadrants and the axial skeleton (Wolfe et al., 2010) or in at least two sections of two contra-lateral limbs and in the axial skeleton (Macfarlane et al., 1996). Leveille et al. (2002) defines widespread pain as pain in the upper and lower extremities and in the axial skeletal region, with moderate to severe pain in at least one region ($\geq$ 4 on a 10-point numeric rating scale where 10 represents excruciating pain). Studies have shown that a pattern of increasing prevalence of widespread pain with age, peaking around the ages of 70 and 80 (Croft et al., 1993; Bergh et al., 2003).

In summary, existing published epidemiological studies of joint pain indicate the following points about chronic musculoskeletal pain: (1) very common among older people (Croft et al., 1993; Leveille et al., 2002); (2) more prevalent in older women (Thomas et al., 2004; Leveille et al., 2005; Munce and Stewart, 2007); (3) fluctuates in frequency over time (Donald and Foy, 2004; Elliott et al., 2002); (5) has low recovery rates (as shown in follow-up studies) (Elliott et al., 2002; Croft et al., 2003; Thomas et al., 2004; Kamaleri et al., 2009); (5) strongly associated with psychological factors (López-López et al., 2008), physical disability (Badley and Tennant, 1992), mental disorders (Munce and Stewart, 2007; Eggermont et al., 2012), social demographics and lifestyle (Urwin et al., 1998; Webb et al., 2003); and (6) justifies active pain management (Donald and Foy, 2004; Maxwell et al., 2008; Grime et al., 2010).

2.7 The effects of chronic pain

2.7.1 The effects of chronic pain on older people's health, well-being and function

Chronic pain can have a debilitating effect on older people's physical and mental health, causing them tremendous suffering and a reduced quality of life. It affects people's well being, their ability to maintain an independent lifestyle, productivity, and social relationships (Breivik et al., 2006; Currie and Wang, 2004; Brown et al., 2011). Older people who suffer from chronic pain commonly experience sleep disturbances (Blagestad et al., 2012), poorer health as well as decreased physical and mental functioning (Helme and Gibson, 1999). They are also more likely to suffer from depression and fatigue (Jakobsson, 2006; Tang et al., 2007; López-López et al., 2008; Bonnewyn et al., 2009). Older people with chronic pain are more likely to experience more physical impairments and disability (Scudds and Robertson, 1998; Thomas et al., 2004). Pain that is widespread affects the progression of disability and physical movement (Leveille et al., 2002). As older people continue ageing, they also tend to experience pain in more locations in their bodies (Thomas et al., 2004; Ahacic and Kåreholt, 2010).

Studies suggest that chronic pain interferes with older people's functional abilities (Ross and Crook, 1998; Leveille et al., 2002; Kamaleri et al., 2008). Kamaleri et al. (2008) found that most respondents in their study reported experiencing musculoskeletal pain at several locations, and localized pain (i.e. pain at a single location on the body) was relatively rare. While localized pain did not appear to have any impact on functioning or daily activities, there was a strong association between the number of pain sites and problems with functional ability. Functional problems among older people increased with the increasing number of pain locations, suggesting that musculoskeletal pain usually coexists with pain in other body regions and that functional consequences are highly dependent on how widespread the pain is (Kamaleri et al., 2008).

2.7.2 The effects of chronic pain on older people's balance

The ageing process is associated with increased risk of disease, health impairments and disability (Kempen et al., 1998). Older people are challenged with age-related sensorimotor changes such as poor eyesight (Lord, 2006), reduced muscle strength (Skelton et al., 1994) and reaction times (Sheldon, 1963; Hageman et al., 1995). While older people already demonstrate greater sideways postural sway[9] compared to younger people (Hassan et al., 2001), those with spine or lower-limb disorders (Boucher et al., 2008) or suffering orthopedic and rheumatologic diseases (Hen et al., 2008; Missaoui et al., 2008) inevitably, have problems with impaired balance and posture. To make matters worse, having chronic pain means that older people face an additional challenge in coping with, or adjusting themselves to these health issues.

Chronic pain has a negative impact on older people's balance. Chronic musculoskeletal conditions such as low back pain (Mientjes and Frank, 1999; Kuukkanen, 2000) and osteoarthritis (Hassan et al., 2001; Boucher et al., 2008) can impair postural control. Balance is essential for safe and independent mobility. While older people with poor balance are at higher risk of falling (Blyth et al., 2007), those with chronic pain are in

[9]the corrective body movement resulting from the control of body position.

the risk category for impaired balance (Kuukkanen, 2000; Iversen et al., 2009), which, recurrently, puts them at risk of falling (Leveille et al., 2002; Sturnieks et al., 2008; Lihavainen et al., 2010).

Older people with lumbar spinal stenosis (LSS) have demonstrated increased postural sway and impaired balance, particularly in the anterior-posterior sway (Iversen et al., 2009). Falling brings dire consequences to older people's health and well-being. Recovery from falling takes a longer time for older people. This limits functional mobility and ambulation, leading to muscle atrophy and a reduced quality of life (Campbell et al., 1981; Leveille et al., 2002). Leveille et al. (2002) reported that there was a higher prevalence of pain coupled with the common occurrence of falls in disabled older women, implying that the role of pain as a contributor to older people's physical impairments subsequently led to increased fall risk. Blyth et al. (2007) found that older people who reported pain with moderate to severe level of pain-related interference with daily activities were more likely to report any falls or multiple falls in the past 12 months compared to subjects not reporting pain. A significant trend indicating an increasing likelihood of self-reported falls with increasing level of pain was found. The relationship between chronic pain and falls was stronger among older people who suffered multiple falls.

Lihavainen et al. (2010) found evidence of a direct relationship between musculoskeletal pain and impaired postural balance in a sample of 605 older women (aged 75 years and above) in Finland. The study measured the participants' balance by using a force platform, and impaired balance was defined as a high sway velocity moment or inability to maintain semitandem standing. The majority of the women experienced moderate to severe pain in their lower extremities or backs, and the prevalence of musculoskeletal pain was estimated at 48% for this population. Participants with moderate to severe musculoskeletal pain had higher sway values while standing, compared to those without pain. After controlling for other predictors (age, gender, body mass, chronic diseases, muscle strength, and physical activity), those with moderate to severe pain were found to have more than twice the risk for impaired balance compared to those without pain.

When compared with non-fallers, studies have found that multiple fallers were more likely to be older and female; to have health conditions such as hypertension and poorer visual acuity. In addition, multiple fallers were more likely than non-fallers to have higher depression, poorer feelings of morale and lower levels of overall well-being (Anstey et al., 2008). The prevalence of depression is higher in older people who fall (Kerse et al., 2008).

A recent study investigated the association of depressive symptoms with fall risk and chronic pain in a sample of 722 older community-dwelling people in Boston. The study reported that higher rates of incident falls occurred to older people who had the highest burden of depressive symptoms (Eggermont et al., 2012). Their main findings concluded that, while depressive symptoms and chronic pain were associated with fall risk in older people, the relationship between depressive symptoms and falling was mediated in part by chronic pain. Although depressive symptoms were significantly associated with chronic pain, there was no strong evidence of any causal relationship where chronic pain leads to depression, which then leads to falls, or the other way round, where depression leads to pain, which leads to falls (Eggermont et al., 2012). A plausible reason could be the complex processes in the underlying mechanisms between falling, depression and having chronic pain. For instance, fatigue due to sleeping difficulties linked with feeling depressed or having chronic pain, could be a contributing factor to falls (Hill et al., 2007; Sivertsen et al., 2009).

2.7.3 The effects of chronic pain on older people's life experiences and expectations

Studies in ageing have examined the experiences of older people living with chronic pain and what it means to them (Sanders et al., 2002; Sofaer et al., 2005; Grime et al., 2010). Older people often portrayed having chronic pain as a normal process of ageing (Higgins, 2005; Grime et al., 2010). There was also a sense of acceptance of pain within the context of their identities as older people (Sanders et al., 2002; Sofaer et al., 2005). When speaking about their symptoms, they often dwelt on the negative connotations of growing old (Sanders et al., 2002). While older people acknowledged the ageing process, they felt it was inevitable that they would experience joint pain and some disability. However, they also perceived the symptoms associated with chronic pain as a major disruption for their everyday activities. This may lead to a withdrawal from their usual social activities (Sanders et al., 2002).

Older people living with chronic pain experience a poorer quality of life as well as unmet needs for health services (Hellström and Hallberg, 2001; Sanders et al., 2002). They are regularly ignored, their complaints often misunderstood by healh care providers, and accordingly they do not receive timely or effective treatment (Walsh et al., 2008). For instance, when requesting for pain relief, medical help almost always came after periods of intense waiting and anxious deliberations about whether to bother the nurse or doctors (Higgins, 2005). Older people also commented that they felt that their requests for analgesia were sometimes forgotten by medical staff (Higgins, 2005). The positive side of formal health services offered to older people is that the assistance and medical care provided have been shown to contribute to an improved sense of wellbeing and significantly reduce the need for acute hospital care (Stuck et al., 1995). The downside is that carers or workers of health services or nursing care may not have sufficient knowledge about chronic pain in older people within their area of responsibility (Olivius et al., 1996). It is also plausible that chronic pain management provided to older people with chronic pain could be inadequate (Chodosh et al., 2004).

2.7.4 Summary

Most studies in the literature have shown that chronic pain is prevalent in older people, particularly in older women. In turn, the high prevalence of chronic pain means that the impact of its effects on older people's health is large. This has important implications for the management and delivery of healthcare and support to older people. Evidence from pain studies highlights chronic pain as a crucial target for improving the lives of older people and the prevention of their balance and functional impairments.

2.8 Exercise for older people

The American College of Sports Medicine (ACSM) and the American Heart Association (AHA) have recommended that adults aged between 18 and 65 years perform moderate-intensity exercise 30 minutes per day five days per week (Pate et al., 1995; Mazzeo and Tanaka, 2001; Haskell et al., 2007). However, those who cannot adhere to these recommendations should still exercise according to how much their own abilities and conditions permit them to do so. In fact, people who perform short-duration exercises such as exercising for up to ten minutes a few times a day, do gain some health benefits (Schmidt et al., 2001). This is the same for those who perform any amount of regular exercise (Chodzko-Zajko et al., 1998; Mazzeo and Tanaka, 2001; Haskell et al., 2007).

Exercise has long been recommended for older people to keep healthy and stay independent (Skelton and Beyer, 2003; Bean et al., 2004; Nelson et al., 2007; Haskell et al., 2007); more especially so for those with chronic pain (Holmes et al., 1996; Rainville et al., 2004), as an appropriately planned exercise programme done consistently is one of the best ways to improve or prevent health problems related to muscles, joints, and bones (Holmes et al., 1996; Taimela et al., 2000; Liddle et al., 2004). Exercise is also a commonly prescribed treatment for people suffering from chronic musculoskeletal pain associated with diseases such as osteoarthritis (Roddy et al., 2005; Jr et al., 1997) and chronic low back pain (Liddle et al., 2004; Rainville et al., 2004).

There are several reasons for older people to exercise. Firstly, the net gain of bone mineral density for older people is modest at a level of 1–3% per year (Suominen, 2007). As evidenced by research, exercise is most effective during bone growth (Bradney et al., 1998). Therefore, bone strength may also improve as a result of exercise, increasing functional capacity and mobility especially towards later old age (Suominen, 2007). Progressive exercise improves the properties of skeletal muscle in men and women up to old age, thus affording them a high reserve capacity for coping with functional demands of physical tasks (Suominen, 2007). Even the very elderly benefits from exercise training where muscle strength and size is concerned (Fiatarone et al., 1994).

Secondly, studies have shown that older people who exercise regularly benefit from improved daily function, fitness and balance (Skelton and McLaughlin, 1996; Feder et al., 2000). There is evidence that exercise can significantly improve dynamic postural stability on older people (Lord et al., 1996). The long-term benefits of regular physical activity aim to reduce the risk of falls and the severity of fall-related injuries (Shumway-Cook et al., 1997; Carter et al., 2001; Suominen, 2007; Sherrington et al., 2008).

Thirdly, exercise does not add to pain aggravation in chronic pain sufferers (Rainville et al., 2004). Contrary to older people's perceptions that making physical movements may sometimes aggravate a painful condition (Jones et al., 1987; Hendry et al., 2006), published studies collectively show a notable and consistent finding that exercise training does not worsen pain or disease progression (Jones and Hoffman, 2006). One example is the significant improvement in impairments in back flexibility and performance of endurance activities in individuals with chronic pain after regular exercise (Leggett et al., 1999). A six-year longitudinal study by Fries et al. (1995) found no evidence of long term physical activity, in particular, running, associated with increases in musculoskeletal pain with age in a sample of 699 people aged between 53 to 75 years, despite the known association of vigorous physical activity with decreased levels of disability and mortality rates in older people. Runners reported slightly less musculoskeletal pain compared to their sedentary counterparts. Furthermore, this slight decrease was statistically significant for regular exercisers who were women. A subsequent study observing the participants for a further 8 years reported similar findings. While there was an increase of pain occurrence with age, there was no progressive increase of musculoskeletal pain in older people who participated in regular vigorous exercise, compared to sedentary older people. Older people who regularly exercised over the long term reported 25% less musculoskeletal pain compared to non-exercisers, either by calendar year or by cumulative area-under-the-curve pain over average ages of 62 to 76 years (Bruce et al., 2005).

Finally, exercise offers a suitable therapeutic recreation for older people who live in long term care (Voelkl, 1990). Exercise helps to overcome problems associated with the loss of self-esteem and independence in long term care facilities. Most older people who enter into institutionalised homes are frail, suffer from comorbid conditions and chronic diseases (Higgins, 2005), and are highly dependent on nursing staff and visiting family members (Stuck et al., 1995). Residents in care live by institutional schedules and are idle most of the day, either doing little or nothing at all (Gottesman and Bourestom, 1974; Harper-Ice, 2002). Participating in exercise may offer them potential to get active and engage in a non-passive activity.

The good news is that there are well-documented positive health and functional benefits associated with exercise (Liddle et al., 2004), as well as strong evidence that inactivity contributes to disability in later life (Jr et al., 1997; Ong and Jinks, 2006). In fact, the general aim of regular exercise for older people with chronic pain is to help them cope with or overcome their pain-related fear of physical movement, and improve their pain and health function (Paist, 1999; Liddle et al., 2004). However, the bad news is that unfortunately, those who stand to gain the most health benefits from exercise tend to be the ones who fail to grasp the therapeutic intent of exercise programmes. Regardless of the known physiological benefits of exercise, older people still demonstrate reluctance or hesitancy to exercise (Crombie et al., 2004). Sedentary behaviour is highly common among older people (Grossman and Stewart, 2003; Kruger et al., 2007). Furthermore, studies have found poor adherence to exercise programmes among older people (Schutzer and Graves, 2004).

The American Geriatric Society Clinical Guidelines on the management of chronic pain in older adults recommends that firstly, exercise programmes should be individualised for each individual. Secondly, graded testing should be made available in order to establish the initial aerobic exercise prescription for the individual, particularly for their cardiovascular response or any other contraindications to exercise. A suitable exercise programme with specific exercise intensity[10], volume[11], frequency[12], and pro-

[10]the amount of muscular effort or exertion put forth during the activity.
[11]the length of time or number of repetitions of which the exercise is to be performed.
[12]the number of exercise sessions per week.

gression[13] can then be planned, taking into consideration which functional problems are important to the individual. In addition, the individual's personal expectations, financial and social resources should be considered, to help accommodate their needs and circumstances, and foster long-term adherence (AGS, 2001).

For older people to exercise regularly, exercise has be appealing to them (Mills et al., 1997; Burton et al., 2012). Simultaneously, it needs to be purposeful, interesting and convenient for older people to be able to do so consistently (Wilcox et al., 1999; Stewart et al., 2001). Fitness routines such as doing sit-ups, jumping jacks, riding a stationary bicycle or stretching may not be enjoyable or motivating. Another important deterrent of exercise is lack of interest among older people (Crombie et al., 2004). This is where exergaming comes in. Exergaming simply combines exercise with video games, and does away with the common discomfort and monotony associated with traditional exercise. Most exergaming applications are designed with game-based, storyline or scenery themes (Gerling, Schulte and Masuch, 2011; Johnston and Whitehead, 2011) which may feature an adjustable level system of ascending difficulty (Betker et al., 2006; Göbel et al., 2010). Because exergaming engages users in game play, the exercise experience becomes more interesting and enjoyable, especially if game levels can be chosen or personalized. Playing games is an entertaining way to keep healthy. Exergaming may stimulate interest in the elderly, motivate them to exercise regularly, or at least at a low or moderate intensity for frequent shorter durations (Gao and Mandryk, 2011).

[13] gradual application of increasing exercise in terms of intensity, frequency, volume, or any combination of these factors, depending on the individual's exercise response.

2.9 Exergaming

Exergaming is commonly defined as a combination of exercise or physical activity with video games (Bogost, 2005; Sinclair et al., 2007; Wylie and Coulton, 2008; Staiano and Calvert, 2011*a*,*b*). In fact, exergaming can be simultaneously mental and physical, or a combination of both because playing games this way requires users to practice their cognitive or athletic skills, or simply concentrate on working different muscle groups or specific exercises. Within the context of exercise, Oh and Yang (2010) redefine exergaming as "an experiental activity in which playing exergames or any videogames that requires physical exertion or movements that are more than sedentary activities and also include strength, balance, and flexibility activities". An example of performing a specific exercise routine in exergaming is cybercyling (Anderson-Hanley et al., 2012).

Both exergames and traditional video games incorporate elements of virtual reality (VR) and animated graphics to allow the creation or simulation of real or imaginary worlds in their game design. However, exergames have the added advantage of using sensing technologies (e.g. immersive video, motion-tracking, or both) (Yang et al., 2006; Göbel et al., 2010). Immersive video technology requires the use of camera-based devices which project the image of the user onto a large video screen where the user sees himself interacting with the exergame elements (Rizzo and Schultheis, 2002; Weiss et al., 2009; Rizzo et al., 2011). Motion-tracking devices consist of either inertia-based devices such as the Wii balance board and tracking gloves or camera-based devices such as the Sony PS2 EyeToy, and more recently, Kinect for Xbox 360. An example of a motion-tracking exergame is the DDR dance pad. It is actually a touch-sensitive foot pad with built-in sensors, which recognise the user's movements

(Bogost, 2005). To play DDR, users dance to the rhythm of the music by stepping, pointing or jumping on a power pad that contains touch-sensitive sensors (Hoysniemi, 2006).

Exergaming can be played in the following ways: control exergaming where body movements are motion tracked into the game (e.g. Wii, Sony Playstation 3), rhythm exergaming where movement is guided by music (e.g. iDance, Rock Band), workout exergaming where users are guided by a virtual fitness trainer and provided with feedback on their workout (e.g. Wii Fit Plus, The Biggest Loser), sensory exergaming which involves physical interaction with light and sound effects (e.g. Makoto Arena II), and exergaming machines where real sports equipment have been fitted with computerized virtual themes (e.g. Gamebike, Exerbike).

2.9.1 Exergaming studies in older people

Recently, exergames have become popular in the research field. During the past 30 years, information has been available from exergaming interventions (Bogost, 2005). These studies have focused on balance (Fitzgerald et al., 2010), motor and neuro rehabilitation (Holden, 2005; Crosbie et al., 2007; Weiss et al., 2009).

A pilot usability study by Kizony et al. (2006) investigated home-based exergaming in older people. A video capture VR system was used in the intervention. Similar to the Nintendo Wii, users stood or remain seated in a designated area in front of a large video screen which displayed the TheraGame exergames. The image of the user was projected on the video screen in the simulated environment. 16 older people ranging from 65 to 78 years of age participated in the study, four of whom had neurological disabilities. Exergames were chosen according to their physical and cognitive abilities. All of the participants experienced a single exergaming session of 30 minutes, playing two games for five minutes each, except one participant with stroke who used TheraGame at home for a period of two and a half weeks. The participants answered questionnaires pertaining to feedback about their exergaming session, the amount of physical effort expended and how usable the exergaming system was perceived to be. Participants reported moderate to high levels of enjoyment and usability. These results suggested that exergaming showed good potential for future home-based use for rehabilitation purposes among older people. Nevertheless, this finding came from data collection after only one exergaming session, which was not affected by external factors such as fatigue and boredom so it was not surprising that the exergaming experience was found to be pleasant and enjoyable.

Anderson-Hanley et al. (2012) investigated the influence of cybercyling in executive function and clinical status among healthy independent-living older people. Sixty-three older people completed the study. The age range was 58 to 99 years. Participants either used a traditional stationary bicycle or a cybercycle which had been fitted with interactive gaming and three-dimensional scenery. The intervention commenced with a one-month familiarisation period followed by gradual increases of exercise frequency to five weekly 45-minute sessions for two additional months. Although both forms of cycling required similar physical effort over the three month testing period, results from the study showed that participants who exercised on the cybercyle had significantly better executive function than those using a traditional stationary bike. The authors maintained that the greater cognitive benefit found in the cybercycle group was attributed to the additional mental effort expended during cybercycling (i.e. the virtual reality experience). This study showed that exergaming with a VR element has potential in improving cognitive health in older people by incorporating mental training with physical effort, implying that exergaming with interactive physical and cognitive exercise may be more beneficial to older people than traditional exercise. However, this finding may be limited to the population sample, as participants were physically healthy, relatively highly educated and ethnicity in the sample was homogenous. The results were analysed taking into consideration full completion of the study and full compliance with the intervention. There may be vast differences in outcome measures between participants who did very well and those who did not complete the study, indicating differences in functioning. Further work is needed to generalize their research findings to older people from different backgrounds and health conditions.

In a feasibility study investigating the use of the Nintendo Wii among older people, Williams et al. (2001) found a significant improvement in Berg Scores among participants who played the Wii at four weeks post-intervention but not at 12 weeks. However, significant improvement in Wii Age scores was found at 12 weeks in the Wii group.The Wii Age scores were calculated by the WiiFit software based on the users' current age, weight and athletic ability. The idea was to get lower scores calculated as the software determines and updates the users' WiiFit age, which loosely suggests their physical performance in relation to their true age. Although these results could not verify long term effects of exergaming on balance, the significant improvement in Wii Age scores were speculative evidence of improved balance in the reduction of WiiFit Age scores at 12 weeks post-intervention.

Bisson et al. (2007) investigated functional balance and dual-task reactions in twelve healthy older people by comparing a 10-week training programme with either computer-based biofeedback training or an IREX^{TM}[14] exergaming programme. Their results showed that all participants improved their functional balance, mobility and reaction time during standing. However, no significant changes in postural sway during quiet stance were found, consistent with previous findings (Lajoie, 2004). The stable values for the root mean square[15] after completion of the training programme suggested that the participants did not have any balance impairments prior to the start of the training, as this was a sample of healthy older people. Although postural sway did not improve, the study showed that there was a likelihood that older people's functional abilities and reaction times could be improved with dynamic training.

Jung et al. (2009) investigated the impact of playing the Wii in comparison to traditional board games on the psychological and physical well-being of reasonably healthy older people living in long term care. Participants were physically able to move around, either independently or with aids, and had adequate function and vision to play the Wii games. Forty-five people, ranging from age 56 to 92 years, participated in three times weekly 1.5 hour sessions for six weeks. The Wii group played Wii Sports games while the control group played traditional games (e.g. memory games, UNO and Jenga).

[14] Interactive Rehabilitation and Exercise System (described in Chapter 3 on page 76)

[15] a statistical measure of the variation in anterior-posterior and medio-lateral standard deviations of the centre of pressure

Questionnaires were used to measure loneliness, self-esteem, balance and physical activity. Results from the study showed that self-esteem affect were significantly higher in the Wii group compared to the control group. The Wii group also reported having experienced higher physical activity in comparison to the control group. While this study aimed to assess the potential of Nintendo Wii in improving the quality of life in older people, it was able to show an improved sense of well-being in the sample. In actual fact, the study showed that participants who played the Wii were slightly happier than their traditional board game counterparts.

Because the study design did not include any physiologic recordings, physical measures were not investigated in this study, excluding any prospect of assessing physical health benefit. The authors stated that their longitudinal comparisons showed no significant positive changes in the control group, thus negating the Hawthorne effect[16]. However, it was unclear how much interaction the participants in the experimental group actually had with the Wii games if each participant averaged 15 minutes per week playing the Wii. An average of 15 minutes per week playing the Wii does not meet the minimum requirement of recommended exercise dose for older adults (Chodzko-Zajko et al., 1998). In this context, short durations of activity allowed participants to maintain sufficient attention while exergaming, resulting in more positive affect and enjoyment in playing, thus eliminating any onset of boredom (Danckert and Allman, 2005). Although the research team was present to supervise and help with technical difficulties, participants answered all questionnaires by themselves. They may have also exhibited higher levels of enthusiasm in their involvement with new technology. There could

[16]a phenomenon in which participants alter their behaviour as a result of being part of an experiment or study.

have been differing self-perceptions on exergaming among participants, for example a participant may have thought that he did very well in the Wii game when in reality, he may have performed poorly.

Another study using the Wii investigated balance and enjoyment in older people (Agmon et al., 2011). The sample comprised 7 people (ranging from 78 to 92 years of age) from retirement communities living in long term care. Participants had impaired balance but were still able to walk 4 metres independently. The intervention consisted of playing exergames for 30 minutes for at least thrice weekly sessions for 3 months. Balance was measured using the Berg Balance Scale (Berg et al., 1992) and using the 4 meter timed walk test. Feasibility and safety were assessed through phone-calls from the research team and via participants' written logs at the end of each exergame session. Participants received adequate supervision from the research team as well as assistance from the residential home staff. Results from the study showed an improvement in balance with the significant increases of Berg balance scores and walking speed. Participants also reported having enjoyed playing the exergames and expressed experiencing better balance with their daily activities. This is an encouraging research finding as participants represented older people with age-related pathologies. Qualitative findings on how the participants felt about their overall balance complemented the quantitative results from the Berg Balance Scale. However, the number of participants was too small, and it was not clear which factor exactly (e.g. exergaming with the Wii or specific Wii game) had any effect on improving balance. This could also not be verified because there was no control group. How much time and effort each participant spent on exergaming could not be ascertained so the research team was unable to precisely determine optimal training for improving balance using the Wii. It was assumed that the participants did not have any previous experience with exergaming. Therefore, as expected, high levels of enjoyment were rated immediately after every session, if exergaming was perceived as new and novel by the participants. The novelty of the exergaming experience could have influenced affective responses from the participants, resulting in high scores for enjoyment (Chen et al., 2001).

Wollersheim et al. (2010) investigated the feasibility of exergaming using the Wii among healthy community-dwelling older people. The sample comprised 11 older women (ranging from 56 to 84 years of age). The intervention consisted of twice weekly exergaming sessions averaging 51 minutes each, for six weeks. Accelerometry was used as a measure of physical effort while focus groups and interviews were conducted to obtain qualitative data. Although no substantial physical effects or differences in physical energy expenditure were found, qualitative results showed that there was an improved sense of physical, social and psychological well-being among participants. Participants also favoured exergames with strong emotional appeal and clearer graphics that could be played in groups. The exergaming sessions also gave them the opportunity to get to know one another. Participants now felt more empowered and confident as they had learned another skill. They could share their experience of this new technology with their grandchildren.

This study showed that exergaming was feasible, safe and beneficial when incorporated into a community health setting. There were mostly positive responses from participants. However, similar to Agmon et al. (2011) and Jung et al. (2009), there were no significant findings in terms of expended physical effort. Most of the participants did the exergames while being seated. Also, the Nintendo Wii requires the use of the handheld remote which means that the operating system tracks and receives signals from the handheld remote. Therefore, the movement of the handheld remote is questionable if only the dominant arm is in use and other parts of the participants' body is at rest. Because there was no proof of increased expenditure of physical effort in exergaming, further work is needed to address the exercise component of exergaming for this population.

To supervise, motivate the participants and ensure that the intervention could run, encouragement in the form of positive feedback was consistently provided by the researchers. While this may have helped the participants in their effort to overcome their own insecurities and perform an activity that was previously unfamiliar to them, this could have also prompted agreeable responses from participants. In this study, the sample were all older women. Women have been shown to foster greater social relationships and co-operation (Wheeler et al., 1983; Abele, 2003). Older people tend to be more obliging and co-operative (Cuddy et al., 2005). Therefore it seemed natural for the participants to have responded favourably throughout the study.

Saposnik et al. (2010) conducted a single-blind clinical trial investigating the effectiveness of VR through exergaming in stroke patients. The mean age for participants was 61.3 years while the age range was 41 to 83 years. All patients received both physical and occupational therapy for stroke. Twenty-two patients were randomised into two groups. One received recreational therapy (i.e. leisure activities such as playing cards, stamping a seal while playing bingo, or playing Jenga) while the other performed exergaming using the Wii. Each participant either played the Wii or received recreational therapy for 8 sessions within two weeks. Outcome measures were focused on feasibiity aspects of using the Wii. Total time receiving the intervention represented the participants' time tolerance and adaptation to playing the Wii. Motor function was evaluated as a measure of efficacy in exergaming. Although the authors could not find any differences in manual dexterity between the two groups, results showed that participants in the exergaming group performed, on average, significantly better in motor function and grip strength.

Although this study provided preliminary findings for future stroke rehabilitation research, it had some weaknesses. The number of participants was small. Similar to other studies, participants in the Wii group may have shown greater levels of enthusiasm. Despite single-blinding, participants using the Wii may have unconsciously disclosed their treatment allocation to the investigator. Despite the encouraging results concerning motor function, the study could not confirm the effects of exergaming because everybody was receiving standard rehabilitation therapy. There were also age differences between the groups where the recreational therapy group was significantly older than the Wii group. Younger members could have exhibited faster reaction times in their exergaming session. Time was also a limiting factor for the study as the intervention took place over two weeks. A longer time would have been more suitable for the estimation of the exergaming effects. Lastly, the research team was not able to verify physical movements made by the participants playing the Wii. Because the Wii relies on signals tracked from the handheld remote, participants may have used their own movement strategies to interact with the exergames instead of using the appropriate designated physical actions or moves. This would have also generated scores on the Wii console.

Perhaps one of the most significant current findings in exergaming research among older people is the enjoyable experience and the psychosocial benefits that it confers. The exergaming research by Graves et al. (2010) compared the physiological cost and enjoyment of exergaming with the Wii Fit with aerobic exercise in three populations: 14 adolescents, 15 young people and 13 older people. Older participants reported having enjoyed balance games the most as some of the balance exercises were self-paced and afforded the opportunity for them to select and perform their own movements. These balance games incorporated yoga postures, muscle conditioning and balance training. Graves et al. (2010) argue that exergaming is still able to stimulate light to moderate aerobic activity in users based on the evidence of greater energy expenditure and heart rate of Wii Fit activities all groups of participants than handheld gaming, despite being lower than treadmill exercise. For older people, the energy cost acquired for the Wii Fit games was comparable to activities of trampolining and walking leisurely (Ainsworth et al., 2000). Because older people have more restrictions in physical movement, the exercises incorporated into the balance games may offer a more pleasant or agreeable way to improve balance and reduce age-related functional impairments (Skelton and McLaughlin, 1996; Carter et al., 2001).

2.9.2 Summary

Numerous studies have evaluated the effects of exercise on older people's health, functioning and balance but very few have applied exergaming interventions in their investigation. Exergaming research in older people is still relatively new. Looking across published exergaming studies, findings have been generally varied as the studies used different exergaming programmes of different durations, and have considerable shortcomings. One example is small sample size. There is also evidence of the positive impact of exergaming on older people's functioning and balance, although results for more in-depth measures of balance are less clear cut. Despite the current lack of empirical evidence of improved physical benefits in older people after exergaming, there may be other positive aspects to assuming that exergaming does a lot of good for older people. In fact, the most promising finding for the future is that older people are mostly happy with exergaming once they started using it. The common finding that exergaming makes exercise enjoyable may justify introducing exergaming to older people.

Yet, considering the potential of exergaming in motivating older people to get them to exercise, older people's perceptions of exergaming in relation to technology acceptance and flow experience have received relatively little attention. Previous studies investigating the effects of exergaming in older people have not applied the theoretical aspects of technology acceptance and flow experience in their investigation. To the author's knowledge, exergaming investigation has not yet been extended to a population of older people with chronic pain concerning factors influencing their exergaming experience or intended future use of exergames as an exercise activity. An important issue that needs attention is older people's thoughts and perceptions about the usefulness of exergaming, including their perceived self-ability, social environment and intention. This also raises the issue of choice which is crucial if exergaming can be perceived as a useful form of exercise.

The current thesis applies the Unified Theory of Acceptance and Usage of Technology (Venkatesh et al., 2003) to understand older people's perceptions of exergaming, which ultimately influences their continued intention to use exergaming, if any. Investigating flow experience in exergaming will provide additional insight into the subjective experience of older people interacting with exergames. Finally, investigating older people's balance after exergaming may provide evidence of exergaming as a worthwhile exercise strategy that could be useful in improving balance in older people.

2.10 Aims of the thesis

1. To investigate older people's perceptions and experience of exergaming

2. To investigate the exergaming experience in older people with chronic pain compared to a standardised exercise protocol

2.11 Research questions

Research questions related to aim 1

R1.1: Are older people likely to accept exergaming in relation to its technology and use?

R1.2: How do older people feel about exergaming?

R1.3: Does older people's previous behaviour influence their future intention to use the exergaming technology?

Research questions related to aim 2:

R2.1: Are older people with chronic pain likely to accept exergaming in relation to its technology and use?

R2.2: Does exergaming have any effect on older people's postural sway in comparison to a standardised exercise protocol?

R2.3: Does exergaming have any effect in older people's self-reported health status, chronic pain and physiological response?

The current thesis comprises two separate studies:

Study 1: Acceptance, perceptions and experience of exergaming in older people

Study 2: Exergaming acceptance and experience in older people with chronic musculoskeletal pain

In study 1, the thesis investigates exergaming within the context of technology acceptance and flow by using the Universal Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) and the Flow State Scale (Jackson and Marsh, 1996), and explores how healthy older people feel about exergaming and whether the technology is acceptable to them.

In study 2, the thesis explores technology acceptance and exergaming experience in older people with chronic musculoskeletal pain. It describes pain in the sample and investigates the effects of exergaming on older people's self-reported health status, chronic pain and postural sway over two conditions of quiet bipedal standing (i.e. eyes open and eyes closed). This is to find out whether exergaming is clinically effective in improving balance after a 6-week intervention.

Chapter 3

First study: The acceptance and experience of exergaming in older people

3.1 Introduction

This chapter describes an investigation into how older people perceive and experience exercising in the exergaming environment. Empirical evidence obtained from a modified Technology Acceptance acceptance and the Flow State Scale (Jackson and Marsh, 1996) as well as evidence from content analysis pertaining to older people's exergaming experience is presented. The organisation of this chapter is as follows: Section 3.2 presents the background of the study, theoretical foundations of the research model modified from UTAUT and the hypotheses related to the investigation of older people's exergaming experience. Section 3.3 outlines the research methodology, outcome measures and data analyses. Section 3.4 describes the results. Section 3.5 then discusses the findings from healthy older people, implications of the study and concludes the study.

3.2 Background

Older people are aware of the numerous health benefits in exercise (Cousins and Gillis, 2005; Bunn et al., 2008). However, studies have shown that a majority of them do not get enough exercise (Brown, Balluz, Heath, Moriarty, Ford, Giles and Mokdad, 2003; Grossman and Stewart, 2003; Schutzer and Graves, 2004; Kruger et al., 2007) and very often, lead sedentary lifestyles (Vuori, 1998; Ng et al., 2009). In fact, sedentary older people already know that keeping active is important to their health and still do not participate in regular exercise (Cousins and Gillis, 2005).

For some older people, deteriorating health actually drives them to increase their daily physical activity, such as taking regular or increasing involvement in walking, jogging, or aerobic classes (Phillips et al., 2004). But for others, exercise can sometimes be forgotten or neglected in the wake of illness, or failing health due to perceived risk, feelings of uncertainty, and fear of physical exertion or exhaustion (Belza et al., 2004; Cousins and Gillis, 2005). Older people also experience age-related health and functional declines (Sinclair and Nayak, 1990; Skelton et al., 1994; Lord, 2006), which discourage them from taking up exercise or being physically active. Psychological factors such as fear of falling, or fear of pain prevent older people from taking up regular exercise (Vlaeyen and Linton, 2000). Another barrier to exercise is simply a lack of interest among older people (Crombie et al., 2004). Other reasons cited for not taking up regular exercise include financial expenses related to exercise programmes, lack of awareness of fitness activities in the area and no means of transportation to the fitness centre (Rimmer et al., 2008). Because of the numerous health challenges and psychological barriers faced by older people, exercise needs to be made appealing to them so that they can be motivated to initiate and maintain physical activity (Phillips et al., 2004).

Exergaming combines video game play with exercise (Oh and Yang, 2010). One of the advantages of exergaming is the provision of indoor exercise, which may appeal to older people who do not like going outdoors (Hug et al., 2009), or are reluctant to engage in the traditional forms of exercise (Crombie et al., 2004). Another is that exergames[1] can be easily learnt and accessed quickly, to offer opportunities for older people to exercise at low to moderate intensities for shorter periods of play (Gao and Mandryk, 2011, 2012). Although evidence of perceived health and social benefits through the exergaming activity exists in the literature (Thornton et al., 2005; Jung, Li, Ng, Wong and Lee, 2009; Agmon et al., 2011; Staiano and Calvert, 2011*a*; Williams, Soiza, Jenkinson and Stewart, 2010; Wollersheim et al., 2010), not much is known about older people's acceptance of the exergaming technology. In the current thesis, older people's acceptance of exergaming technology is represented by their behavioural intention to use the technology, if made readily available. However, before proceeding any further, it is essential to understand the differences in technology use among older people today.

Older people today did not grow up playing video games or surfing the Internet. Instead, consumer devices[2] used in their formative years[3] revolved around either mechanical or electro-mechanical interfaces (Docampo-Rama and van der Kaaden, 1998).

[1] digital games within an exergaming system such as Bowling from Nintendo Wii
[2] such as radio, telephone, television, sewing machines and washing machines.
[3] a transitional period of development between youth and maturity.

The lack of money available during the Depression[4] meant that as children, they had to make up their own fun and games. This also persisted in the generation of people born after the second world war. Games like hopscotch and hide and seek were played, including many different sport. Social activities included dancing, skating and community activities (Genoe and Singleton, 2006). The generation of older people born between 1942 and 1953 also grew up in households using electro-mechanical user interfaces. The introduction of software-style games in the 1980s (Bogost, 2005) occurred when most of them were already adults. A digital gap between generations exists, even for younger parents (i.e. those born after the 1950s) and their children (Clark, 2009). In days when there was no email, letters were sent by post, people used the telephone and urgent messages were delivered by telegraph (Baron, 2000).

Despite recently reported increasing numbers of older Information and Communications Technology (ICT) users (Goodman et al., 2003*b*; Melenhorst et al., 2006), evidence shows that many older people are still missing out on benefits offered by technologies such as mobile phones (Kurniawan, 2008), computers and the Internet (Morris et al., 2007). In fact, people aged over 65, tend generally to be among the late adopters of new technology (Matilla et al., 2003).

Would older people be willing to play virtual bowling games when they had, in their youth, bowled with a real bowling ball and scored points by knocking down real bowling pins? Internet banking offers customers access to banking transactions which can be done in the privacy of their own homes (Tan and Teo, 2000), but older people who

[4]a period during the 1930s when there was a worldwide economic crisis and mass unemployment.

did not use Internet banking cited the lack of personal service as the biggest barrier to adopting this technology (Matilla et al., 2003). Becker and van de Goor (1997) found that people who experienced the availability of the same types of consumer product during their formative period, in some respects display similar technology usage many years later. If this is true, then whether or not exergaming technology is acceptable to older people is of particular importance, given the numerous perceived health benefits of exergaming.

The Unified Theory of Acceptance and Use Technology (UTAUT) (Venkatesh et al., 2003) has been used by researchers in the field of Information Systems (IS) to study technology acceptance of users in their intention to use information systems. It has also enabled the study of user acceptance from populations that may be less inclined to adopt and use new information systems. The UTAUT model was presented earlier at Figure 2.1 on page 15. The current thesis applied a technology acceptance model modified from UTAUT in its investigation of factors that influence older people's acceptance of exergaming.

3.2.1 The modified UTAUT model

The UTAUT was modified for this study. The original UTAUT questionnaire was also adapted so that the technology acceptance variables relevant to older people's exergaming experience could be measured (see page 260). This enabled the investigation of older people's perception and experience of exergaming. Here, performance expectancy refers to older people's perceptions that performing exergaming will help them to derive benefit from exercise. Effort expectancy refers to older people's perceptions of how easy it is to exercise in an exergaming environment. Social influence refers to the social environment that influences older people to use exergaming. Facilitation conditions refers to older people's competency in using the exergaming system to perform exercise. Self-efficacy refers to how confident older people are of using the exergaming system for exercise and behavioural intention refers to older people's intention to use exergaming if it were readily made available.

Although the main predictors from UTAUT are performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC), UTAUT was modified so that only three main predictors were selected. They were PE, EE and SI, which were direct determinants of behavioural intention (Venkatesh et al., 2003). Age (AGE) and gender (GDR) were selected as predictors of older people's behavioural intention following evidence from previous studies (Comber et al., 1997; Eglesz et al., 2005; Hartmann and Klimmt, 2006; Cherney and Poss, 2008; Lam et al., 2011). Studies have reported that young people aged between the ages of 14 and 18 spent a great deal of time playing computer games, but weekly time of playing gradually decreased as they grew older (Eglesz et al., 2005). There is also evidence of different game preferences between males and females (Buchman and Funk, 1996; Hartmann and Klimmt, 2006). Men tend to perform better when playing video games that involve visual-spatial tasks such as navigating and shooting compared to women (Cherney and Poss, 2008). Boys have been reported to play exergames more actively than girls (Lam et al., 2011). Although the effects of gender and age differences on computer use have previously been reported, this has largely concentrated in the younger age group. It would be interesting to investigate these effects in an older age cohort. The modified UTAUT model is presented at Figure 3.1.

Facilitation conditions was not included because there were no further provisions to provide exergaming equipment for the sample of participants, hence, usage behaviour could not be measured. Furthermore, experience was not measured because participants did not have previous experience with the equipment used for exergaming. Voluntariness[5] was also not relevant for the modified model because all participants would have already consented to using the exergaming intervention in the study. The investigation of voluntariness in previous studies mainly revolved around the use of IS applications among employees at work-places (Venkatesh and Davis, 2000; Venkatesh and Bala, 2008*b*). The selection of age and gender as predictors was based on published studies on the effects of age and gender on computer game-playing behaviours (Hartmann and Klimmt, 2006; Lam et al., 2011). Most studies that have investigated these differences are focussed on younger people, justifying a need to consider how older people are affected, especially if they are to be introduced to newer ways of exercising.

The modified model was also adapted to simulate the research model of Davis and Venkatesh (2004) to examine the influence of older people's previous behavioural intention on future intention to use exergaming (described at Section 3.2.2). The definitions of the variables in relation to the original UTAUT constructs were presented earlier in Table 2.1 on page 18. The original and modified technology acceptance question-

[5]defined as "the degree to which use of the innovation is perceived as being voluntary, or of free will" (Moore and Benbasat, 1991)

naires are presented at Appendix B on pages 260 and 264.

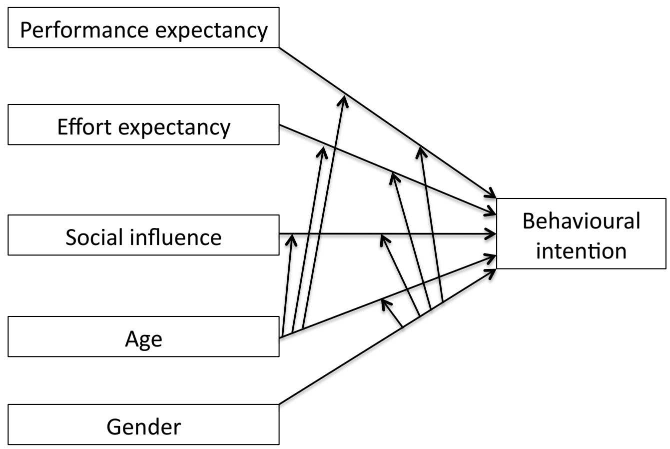

Figure 3.1: The research model modified from Venkatesh et al. (2003)

According to the modified model, performance expectancy (PE), effort expectancy (EE), social influence (SI), age (AGE) and gender (GDR) all influence older people's behavioural intention[6] to use exergaming in future, if made readily available. The modified model is shown at Figure 3.1. Thus, within the context of exercise and exergaming, the following hypotheses based on behavioural intention as a dependent variable were examined in the current thesis:

H$_a$: Older people's perceptions of gaining health benefits from exergaming positively affect their behavioural intention to use it;

H$_b$: Older people's perceptions of the level of ease while exergaming positively affect their behavioural intention to use it;

H$_c$: Older people's social environment positively affect their their behavioural intention

[6]a person's subjective probability that he will perform some behaviour (Fishbein and Ajzen, 1975).

to use exergaming;

H_d: Age negatively affects behavioural intention to use exergaming; and

H_e: For gender, behavioural intention in older men is positively affected, compared to older women.

3.2.2 The influence of previous behaviour in technology acceptance

Based on the substantial body of research investigating associations between past behaviour, intention and future behaviour, the modified UTAUT model was adapted to investigate the influence of older people's early perceived behavioural intention[7] as well as their preceding behavioural intention on their subsequent intention to use exergaming technology. Studies have shown that repeated behaviour or a measure of self-reported frequency of past behaviour contributes to the prediction of future behaviour (Aarts et al., 1989; Norman and Smith, 1995; Ouellete and Wood, 1998; Conner and Armitage, 1998; Venkatesh and Davis, 2000; Rhodes and Courneya, 2003; Davis and Venkatesh, 2004). Intention to use a technology has been shown to be the strongest predictor of usage behaviour in the area of user acceptance of technology (Venkatesh and Davis, 2000; Davis and Venkatesh, 2004). The influence of previous behaviour in predicting future behaviour was initially described in the Theory of Planned Behaviour (Ajzen, 1991). People's decisions are influenced by their previous perceptions, attitudes and experiences (Aarts et al., 1989; Lechner et al., 1997; Ferguson and Bibby, 2002). A recent meta-analysis on the relationship between attitude and behaviour also supports this pattern (Glasman and Albarracín, 2006).

[7] Perceived behavioural intention measured before trying out the exergames (at T0).

Nevertheless, Davis and Venkatesh (2004) have shown that perceived measures of usefulness of a particular technology from users who have not had direct hands-on experience but have only received information about the functionality of the technology were also significantly predictive of usage intentions and behaviour up to six months after workplace implementation. Therefore, knowing how a technology works and what it could do even without trying it out could influence users' future intention to use that technology. In other words, users' early reactions influence subsequent usage behaviour, which in turn, influences future usage behaviour. This also suggested that user-acceptance of a particular technology could be effectively measured at the early stages of implementation. Interestingly, Davis and Venkatesh (2004) found that when previous usage significantly determined future usage behaviour, the other constructs[8] that were measured previously became non-significant. This emphasised the importance of previous usage behaviour in driving future usage behaviour in using a particular technology. Figure 3.2 shows the research model from Davis and Venkatesh (2004).

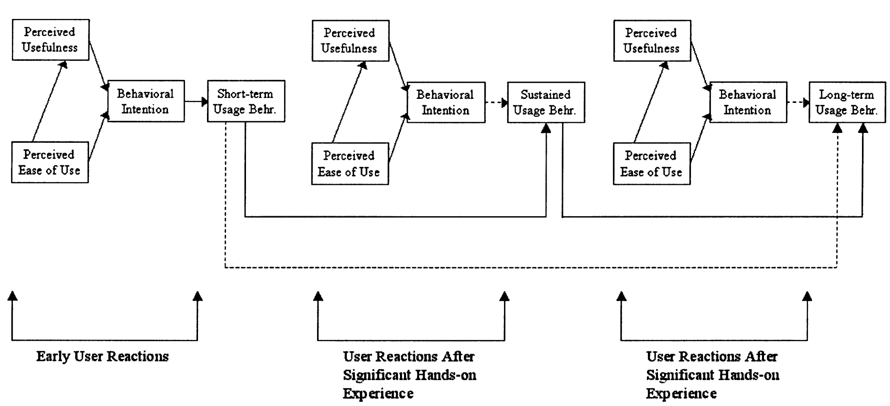

Figure 3.2: Research model from Davis and Venkatesh (2004)

[8]perceived ease of use, perceived usefulness and behavioural intention.

There are two lines of research regarding past behaviour. Research in the first line does not accept the relevance of past behaviour as a major predictor of intention, but acknowledges the multi-functionality of past behaviour in influencing behavioural constructs (Ajzen, 2002; Bamberg et al., 2003). Multi-functionality in past behaviour refers to the formation of habits (Ouellete and Wood, 1998) or attitudes (Glasman and Albarracín, 2006) associated with a particular behaviour; how past behaviour is associated with intention also depends on the type of behaviour that is investigated. An example of a habit associated with past behaviour is demonstrated in the work of Bentler and Speckart (1979). In their study, investigating young people's alcohol and marijuana consumption, their data of self-reported frequency of this behaviour suggested that these actions became habits over time, and the act of consuming alcohol and marijuana could also be triggered by impulse or instigated without much deliberation. Therefore, the measure of habit of substance consumption due to repetitive past behaviour had a stronger influence on future behaviour. A meta-analysis by Albarracín et al. (2001) on sexual behaviour found that unstable contexts such as condom use prevented habituation of that behaviour. Therefore, past behaviour did not have a major influence in the intention of condom use.

Research in the other line views past behaviour as a predictor of intention (Rhodes and Courneya, 2003). Sommer (2011) stresses the importance of previous behaviour in explaining human behaviour, and argues that past behaviour should be included as an independent construct in modelling human behaviour. In their study investigating women's participation in a breast cancer screening programme, Lechner et al. (1997) found that past participation in breast-cancer-screening was strongly associated with positive determinants (such as attitude, anticipated regret, moral obligation) towards future screening participation, with the positive intention to participate in the next screening. Past behaviour and intention significantly predicted participation in the subsequent screening programme in women who had previously attended a breast-screening programme, but not in women who had not participated.

Figure 3.3 (presented on page 72) shows how the modified UTAUT model was adapted in order to investigate the influence of older people's previous and preceding behavioural intentions on their future intention to use exergaming. It appears that this has not previously been investigated before in the literature. Investigating these effects would help us to understand if older people's exergaming experience[9] influenced their future intent to use the technology. Thus, the following hypotheses based on behavioural intention as a dependent variable were examined in the current thesis.

H$_f$: Older people may form significant future behavioural intentions to use exergaming without direct hands-on exergaming experience;
H$_g$: Older people's previous behavioural intention will positively influence their future intention to use exergaming technology;
H$_h$: Older people's previous and preceding behavioural intentions will positively affect their future intention to use exergaming technology.

Thus, the purpose of this study is to investigate, in a laboratory setting, older people's experience of exergaming, as well as the usability of a selected exergaming environ-

[9]represented by their previous behavioural intention.

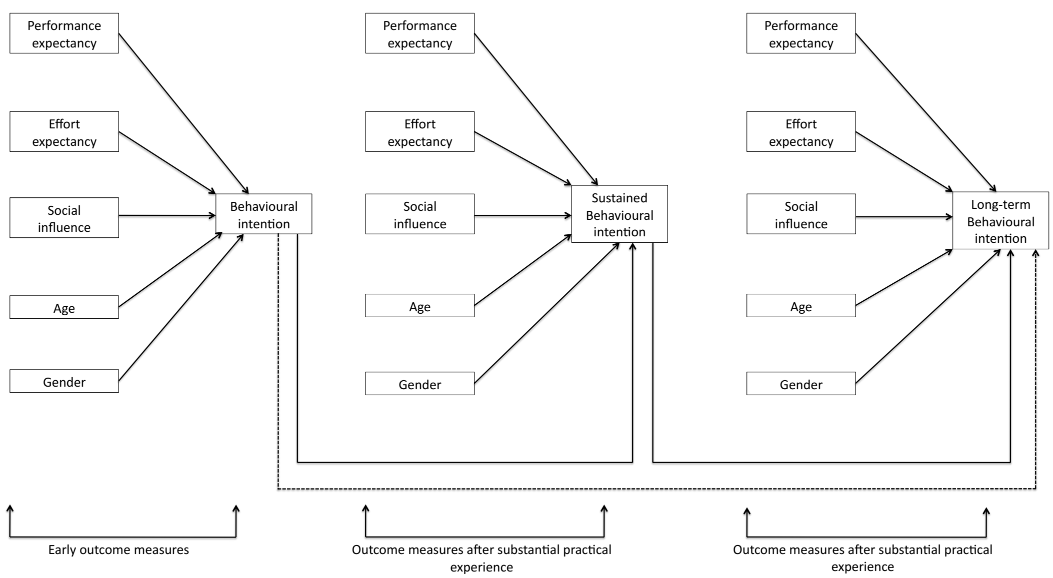

Figure 3.3: Modified UTAUT model in adaptation of Davis and Venkatesh (2004)

ment, for older people who already exercise. The primary aim was to test if, having completed a programme of exergaming, they considered themselves more or less likely to continue to take part in that form of exercise. Secondary aims were to test (on a number of different factors) if perceptions of other aspects of usability, and their experience of exergaming, changed after completion of the programme.

3.2.3 Measuring older people's flow state while exergaming

As flow is also represented by interest and motivation (Csikszentmihalyi, 1990), the concept of flow is a helpful starting point to understand if older people are willing to continue exergaming to their advantage. Investigating flow experience in exergaming provides additional insight into the subjective experience of older people interacting with exergames. The current thesis measured flow variables of older people's exergaming experience by using the Flow State Scale (FSS) (Jackson and Marsh, 1996). The FSS is a 36-item instrument that consists of nine sub-scales of which measure four items each, related to the flow variables (see Appendix B.3 on page 265). The scale has been extensively used and validated (Jackson and Marsh, 1996; Tenenbaum et al., 1999; Fournier et al., 2007; Kawabata et al., 2008; Calvo et al., 2008). The flow variables (i.e. Autotelic experience, clear goals, challenge-skill-balance, concentration at task, paradox of control, unambiguous feedback, action-awareness-merging, transformation of time and loss of self-consciousness, respectively) are described earlier in Chapter 2 from page 19 and defined at Table 2.2 on page 22.

3.3 Method

3.3.1 Study Design

The design was an observational longitudinal cohort study.

3.3.2 Location and Governance

Ethics approval was sought from and granted by the School of Health and Social Care Research Governance and Ethics Committee at Teesside University on 20th May 2009 (see Appendix D.1 on page 284). The study was conducted in the Physiotherapy Research Laboratory, Constantine Building, Teesside University.

3.3.3 Recruitment

Participants were recruited from seven community-exercise groups (groups doing yoga, aerobics and active dance or Tai-Chi) using convenience sampling according to defined eligibility criteria. The definition of the participants as over 50 years is consistent with current definitions of "older" (Hill and Brettle, 2005). There was no maximum limit of age as that would rule out possible participants for no reason other than their chronological age. The sampling frame of older people who were active in exercise classes allowed the study to focus on the impact of the exergaming system. If the sampling frame included people who had no profile of exercising then the exergaming experience would have been blurred by the novelty of exercising.

Inclusion criteria were the following: Aged 50 years and above, currently participating in a community exercise group, able to walk unassisted, and able to read and write

English. Exclusion criteria[10] were the following: Current, or history of any condition or injury which would contraindicate participation in the exercises under study (verified by self-report), having acute/subacute[11] musculoskeletal injury (verified by self report), awaiting or currently undergoing, or having taken part in within the last 12 months, rehabilitation for any musculoskeletal, neurological or cardiorespiratory health conditions (verified by self-report where controlled self-management using pharmacological or non-pharmacological methods does not constitute rehabilitation in this context), inability, or any doubt of ability, to give informed consent, and inability to comprehend and write English.

Managers of sports centres hosting these groups, or, the instructors of those groups were contacted by telephone to ask if they would pass on recruitment pamphlets (see Appendix D.2 on page 286) to any members of their group who were eligible and interested in participating. People who were interested in taking part were asked to give their contact details by filling up a Reply Slip (see Appendix D.3 on page 287) to the sports centre manager or instructor, who then passed those to the researcher.

3.3.4 Participants

Twenty-eight participants (22 women, 6 men) were recruited (age range 50–85 years, mean 65 years, SD 8, height mean 163.40 cm SD 4.50; weight 70.05 kg SD 12.40). Figure 3.4 shows the CONSORT flow diagram of their recruitment.

[10] Previous exergaming experience was not an exclusion criteria.

[11] 12 weeks since occurrence.

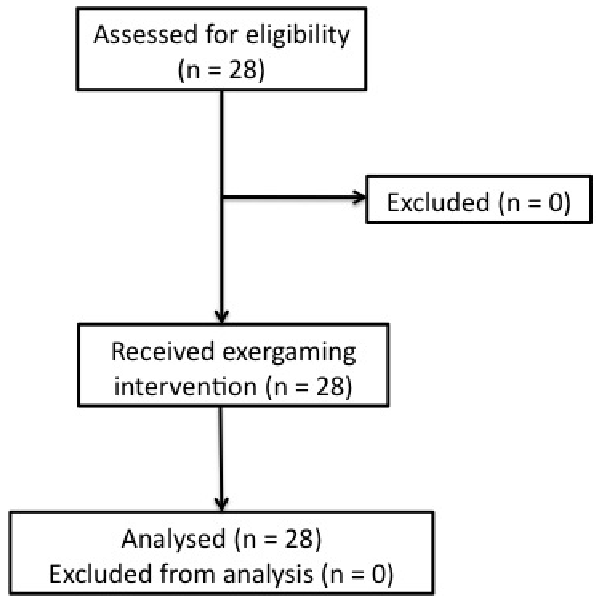

Figure 3.4: The recruitment of healthy older people

3.3.5 Equipment

The Interactive Rehabilitation and Exercise system (IREX^{TM}) (GestureTek, Toronto, Canada) was used to provide the exergaming intervention. It consists of a computer installed with virtual-reality (VR) software, a television monitor with widescreen plasma screen (37", Hanspree, Type T73B, Greyenstraat 65, Netherlands), a digital camera, a green fabric screen (W 3m x H 2.6m) and red gloves (see Figure 3.5).

The software includes over 30 different immersive game applications which can be configured to an exercise protocol specially customised to the user. The digital camera projects the participant's own image on the television monitor, which also shows virtual objects and scenes related to the particular game. The participant wears red gloves and the system tracks the movement of the gloves. The participant interacts with the

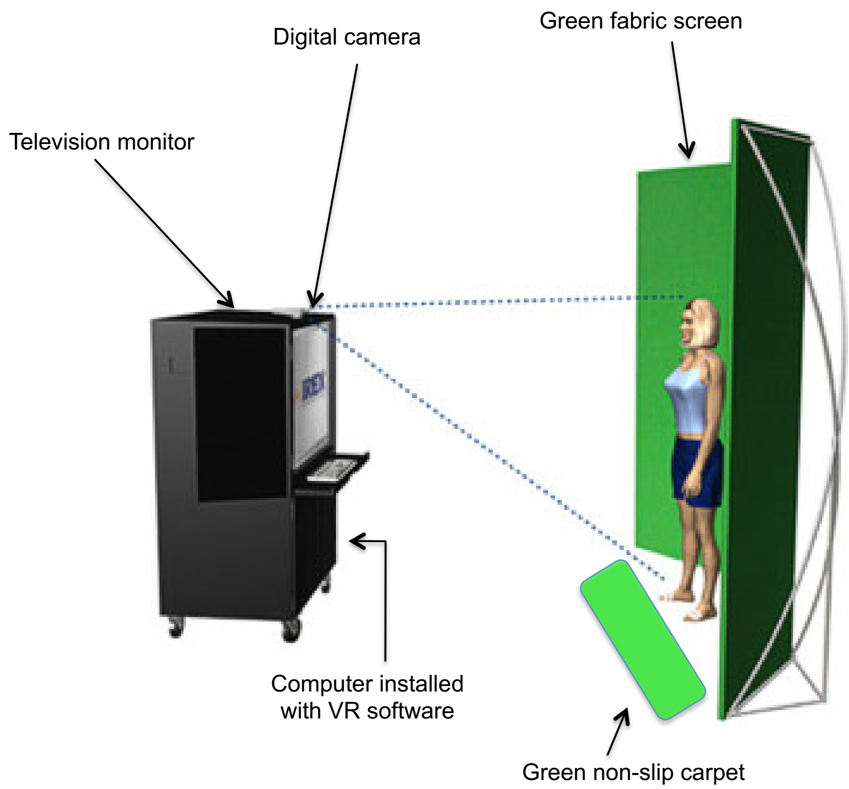

Figure 3.5: The IREX^{TM} system (GestureTek, 2008)

exergaming environment by, for example; moving to steer a virtual racing car, crouching or ducking to avoid an obstacle during exercises (see Figure 3.6 on page 78).

Figure 3.6: A participant performing a lunge during an exergaming session

3.3.6 Outcome measures: Quantitative

The outcome measures were variables of technology acceptance (i.e. performance expectancy, effort expectancy, social influence, self-efficacy, facilitating conditions, and behavioural intention), where behavioural intention was the dependent variable, variables of flow, perceived levels of expanded physical and mental effort, and participants' opinions about the experience of exergaming. These variables were measured using a modified technology acceptance questionnaire (see Appendix B.1 on page 259).

Flow variables (i.e. autotelic experience, clear goals, challenge-skill-balance, concentration at task, paradox of control, unambiguous feedback, action-awareness-merging, transformation of time and loss of self-consciousness) were measured using the Flow

State Scale (Jackson and Marsh, 1996) (see Appendix B.3 on page 265).

The Borg 6–20 Rate of Perceived Exertion (RPE) scale (Borg, 1970*a*,*b*) was used to assess the amount of perceived physical exertion in older people (see Appendix C on page 282). The RPE is a subjective scale most commonly used in studies of rehabilitation settings or physiological responses such as heart rate and oxygen uptake (Borg et al., 1987; O'Neill et al., 1992; Eston and Connolly, 1996; Chen et al., 2002; Eston and Evans, 2009; Eston, 2009; Karavatas and Tavakol, 2005). It is also recommended for assessing levels of perceived exertion and predictions of exercise intensity during sports (ACSM, 2000). The RPE scale applies verbal anchors and numbers that allow participants to describe the amount of strain or level of physical exhaustion corresponding to numerical forms during the intervention (Borg and Lindblad, 1976; Borg, 1998). Verbal anchors on the RPE scale have been found to be consistently rated by most clinical subjects (Dawes et al., 2005). Examples of numerical ratings are 6 which is "very, very light", 8 is "very light", 13 is "somewhat hard", 15 is "hard" and 20 is "very, very hard".

The Subjective Mental Effort Questionnaire (SMEQ) (Zijlstra, 1993) was used to obtain measures of subjective mental effort during the intervention (see Appendix C on page 283). The SMEQ is a one-question univariate scale ranging from 0 to 150 with nine descriptive indicators along the axis, ranging from "absolutely no effort" to "extreme effort". It has been used in many areas of research including information systems (Carsten, 1999) and usability studies (Sauro and Dumas, 2009; Hassenzahl and Sandweg, 2004), medical research (van der Schatte Olivier et al., 2009) and humanmachine interaction (Carsten, 1999).

3.3.7 Outcome measures: Qualitative

Older people's personal opinions of the exergaming experience was captured with a single open-ended question “What did you think of the session?" posed to participants upon completion of each exergaming session. Written or verbal responses from participants were recorded by hand by the author of this thesis. This qualitative data was included to try to gain a deeper insight into participant's perceptions and experiences of using the exergaming technology for exercise.

3.3.8 Procedure

On arrival for data collection at the Physiotherapy Research Laboratory at Teesside University, participants were asked if they had further questions about the study. These questions, if any, were answered by the researcher. The Informed Consent Form (see Appendix D.5 on page 300) was then signed. The time of data collection of which was suitable and convenient to the participants was arranged with them. All participants were asked to report to the laboratory twice a week for 40 minutes each session over a three week period.

Demographic data including weight (kg); height (cm); age (years); gender (M/F) was then recorded for each participant (see Appendix D.6 on page 302). Prior to any exergaming taking place, participants were asked to complete the modified Unified

Theory of Acceptance and Use of Technology (UTAUT) questionnaire. This provided baseline measures for the technology acceptance outcome measures (i.e. at the first time point, T0).

Following this, the researcher showed all participants examples of the physical movements for the IREX^{TM} game applications. After this, participants exercised using the IREX^{TM} system, of which each game was repeated three times. Participants were given adequate rest between applications, ranging between 10 to 30 seconds, or more, if desired. Levels of exercise available in the IREX^{TM} applications ranged from 1 to 10 where 10 was the most challenging. Participants interacted with the applications at their own pace; they all started at level 1 and in subsequent sessions they were allowed to adjust the level as they wished.

Participants were asked to rate how much physical exertion and mental effort they had expended during the game applications by using the BORG and SMEQ scales. This occurred three times during each exercise session (i.e. after 15 and 30 minutes, and at the end of the exercise activity).

Upon completion of the entire exergaming session which meant that participants had finished playing the five exergames, the modified UTAUT questionnaire was once again administered to the participants to capture their thoughts and views about the exergaming technology. This served as outcome measures for the first time after having exergamed (i.e. T1). After this, they were invited to answer the Flow State scale. This provided outcome measurements for variables of flow after having tried the exergaming system at T1.

After completing the Flow State Scale, participants were shown a blank piece of paper with a single statement printed as such, “What did you think of the session?”. They were invited to answer this question either in writing or verbally. Verbal answers were written down by the researcher. This procedure was repeated at every session, which enabled the collection of data at six time points (T1 to T6) during the intervention.

3.3.9 Exergaming intervention

The exergaming programme consisted of six 40-minute exercise sessions within a three-week period (presented at Table 3.1). Each exergaming application that comprised two minutes duration was repeated three times within a session. All participants were also given rest periods of 10 to 30 seconds, or longer, if required, between exergaming applications.

Table 3.1: Exercise intervention for the experimental group

	Purpose	Exergaming instructions
1	To encourage physical movement of the upper extremities and balance 	Volleyball: Land the ball in your opponent’s court or outside your court. Either move your body, shoulder or touch the volleyball by hand. Smoother movements allow better contact with the ball.

2	To encourage full body movement with bending and stretching 	Sharkbait: You will see yourself virtually deep-sea diving with sea creatures. Catch as many stars as you can. Lean side-by-side, crouch down or raising your arms. To move sideways quickly, step to the side. If you meet a shark, it will virtually swallow you and expel you out of its mouth. Contact with an electric eel virtually temporarily disables your movement.
3	To encourage trunk mobility, movement of the upper torso and balance 	Formula racing: You will see yourself virtually driving in a Grand Prix. The course of the track is also visible to you. Drive through the racecourse as best as you can. Steer by stepping to the right or left, by moving your body to the side, or by moving one arm at a time. If you feel that you have not moved on the track, take one small step to the side to move your car.

4	To encourage full body movement, working on pelvic tilt and hamstrings 	Snowboard: You will see a red silhouette of yourself standing on a snowboard, coming down a narrow slope, and a virtual image of yourself when you cross the finish line. Begin by stepping sideways until you are centred over the snowboard. Make as many jumps as possible and avoid hitting other objects. Lean to either side, or move your arm to one side.
5	To encourage shoulder rotation, fine motor exercise and movement of the upper extremities 	Soccer: You will virtually be a soccer goalkeeper. Protect your goalpost, do not let any balls score on the net behind you. Keep the balls away by touching the balls with any part of your body.

3.3.10 Data analysis

Acceptance and flow measures

Data were analysed using version 16.0 of the Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL, USA). To evaluate internal consistency of the measurements, Cronbach's alpha was calculated within each scale for all exergaming sessions. Model testing was conducted using hierarchical multiple regression. Repeated measures one-way ANOVA was used to analyse the changes in outcome measures for all time points. Greenhouse-Geisser adjustment of the degrees of freedom was applied to correct any violation of the assumption of sphericity.

Changes in acceptance scores were calculated as the mean difference between before and after participating in all the exergaming sessions. Changes were also calculated for mean differences in flow scores obtained between the first and last exergaming sessions. These scores were then compared using Student's t test. Cohen's d was calculated to estimate the effect size of the comparison between the means.

Traditionally, studies report inferences about true (population) values of an outcome statistic by declaring the value statistically significant or non-significant based on the derived p value from a null hypothesis test. However, this approach may be misleading because of the magnitude of the statistic, error of measurement and sample size (Batterham and Hopkins, 2005). Batterham and Hopkins (2005) argue that the ambiguity of the true value of the statistic can be shown in confidence limits, which in turn define the regions of beneficial (substantially positive), trivial (negligible), and harmful (substantially negative) values. Clinical significance is interpreted by confidence limits in relation with the smallest or most minimal clinically beneficial or harmful effects (Hopkins, 2003; Batterham and Hopkins, 2005). This approach is described in detail in Hopkins et al. (2009).

In the current study, measures used to estimate the effect were the standardised observed value of the effect, its *p*-values and the smallest substantial values for the effect (here it is the smallest important value of the mean difference between T0[12] and T6 for technology acceptance; T1 and T6 for flow, perceived physical and mental effort). The calculations were based on the same assumption of a normal or *t* sampling distribution that underlies the calculation of the *p* value for these statistics. The smallest important values of the mean differences in all outcome measures before and after the exercise sessions were taken as 0.5SD of the baseline scores. The terms “substantially positive/beneficial”, “trivial/negligible” and “substantially negative/harmful” are used to describe the estimated effects.

Mechanistic[13] effects are shown as unclear if the confidence limits overlap values that are substantial in a positive and negative sense. The estimated effect is then described as “negligible”, “positive” or “negative”. When making a clinical inference, the estimated effect is described as either “beneficial”, “harmful” or “trivial” if the confidence limits show chances of benefit that may be promising yet overlaps values showing risk of harm. According to Batterham and Hopkins (2005), an effect should be almost certainly not harmful ($<$5% chance) and at least possibly beneficial ($>$25% chance) before an intervention or treatment is to be used. If chances of benefit were higher than chances of harm, for example 85% benefit and 2% harm, the intervention or treatment would be deemed clearly useful. The current thesis used a spreadsheet provided by Hopkins (2007) to estimate any clinically or practically important effect of exergaming. The spreadsheet converts *p* values into confidence intervals based on the same as-

[12]time point where T0 is the baseline measure before the first exergaming session (T1).

[13]“the nature of decisions about the clinical application of effects that a chance of using a harmful effect (Type I error) has to be a lot less than the chance of not using a beneficial effect, no matter how small these chances might be.” (Hopkins, 2007)

sumption of a normal or *t* sampling distribution that underlies the calculation of the *p* value for these statistics. Figure 3.7 shows the range of values for clinical inference using chances of benefit, trivial and harm.

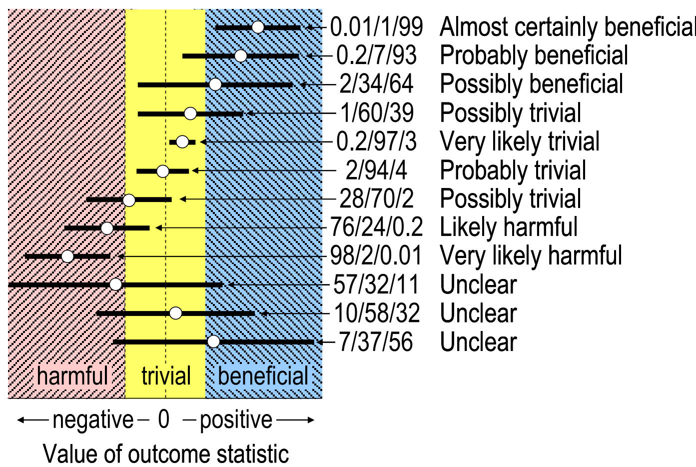

Figure 3.7: Ranges of confidence limits expressed by three-level scale magnitudes. The numbers show quantitative chances (%) that the true value of the effect is harmful/trivial/beneficial (Batterham and Hopkins, 2005)

Exergaming experience

Answers to the open-ended evaluation were analysed by content analysis (Riffe et al., 2005) to identify substantial themes or categories from the data. Multiple responses to the open-ended evaluation were coded by the author and two independent raters. The coding system (see Appendix D at page 303) was explained to the independent raters. The raters also discussed the research question, the data to be coded and the rules of interpretation. The coding protocol was tested by coding two records of data collectively. Following this, the rest of the data were rated independently. Interrater reliability (Hayes and Krippendorf, 2007; Krippendorf, 2004) was assessed using Fleiss' kappa

Table 3.2: κ values in rating agreement (Landis and Koch, 1977)

< 0	Poor agreement
0.0–0.20	Slight agreement
0.21–0.40	Fair agreement
0.41–0.60	Moderate agreement
0.61–0.80	Substantial agreement
0.81–1.00	Almost perfect agreement

via ReCal 3, an online interrater reliability service (Freelon, 2010*b*) (see Table 3.2 for the numerical κ values in rating agreement (Landis and Koch, 1977)).

Older people's behavioural intention to use exergaming

Technology acceptance data was used for analysis by moderated multiple regression. As a precaution to avoid the problem of multicollinearity that biases multiple regression, correlation coefficients between predictor variables (presented at Appendices F.1–F.7 on pages 312–318) and variance inflation factors (VIF) (shown at Appendices F.20–F.22 on pages 328–330) were calculated. In addition, the centering method approach (Aiken and West, 1991) was followed in which data was centered by transformation into deviation score form with means equal to zero. Multicollinearity was examined with correlation coefficients (predictors with significant and correlations exceeding 0.8 are indicative of multicollinearity) and inspection of the variance inflation factor (VIF) for each predictor (VIF values that exceed 10 warrant caution (Myers, 1990) and if the average VIF value exceeds 1, then the model may be biased by multicollinearity (Bowerman and O'Connell, 1990). In addition, *F*-values for the mean-squared residuals were calculated to test the R^2 changes in the models between time-points.

In Model 1, the dependent variable was BI. Predictors entered into the regression were performance expectancy (PE), effort expectancy (EE), social influence (SI), age (AGE) and gender (GDR). The model was regressed using the enter method for every time point[14]. Hierarchical regression was also applied when products between the predictors were included in the model. In the first block, direct effects (PE, EE, SI, AGE and GDR) were entered. Next, interaction terms (PE x GDR, EE x GDR, SI x GDR, PE x AGE, EE x AGE, SI X AGE and AGE x GDR) were entered in the second block.

In Model 2, in the first step, (1) BI from the previous session, (2) the main effects (PE, EE, SI, AGE and GDR), and (3) the two-way interaction terms (BI x GDR and BI x AGE), were entered, respectively (see Figure 3.3 on page 72).

In Model 3, the equation included not only the previous BI but also the preceding BIs measured in earlier sessions. The independent variables were entered into the regression equation in two successive steps. In the first step, (1) the previous BI and any BI that precedes the former, and (2) the main effects (PE, EE, SI, AGE and GDR). Because the presence of two-way interactions were suggestive of multicollinearity (Aguinis, 1995; Blalock, 1963), they were not included in the model.

The next section addresses the research questions (R1.1, R1.2 and R1.3) related to Aim 1 (see page 57). It informs the internal reliability of measurement scales using Cronbach's coefficient alpha estimate and descriptive statistics for outcome measures. Results of the repeated measures one-way ANOVA, *t* tests, confidence intervals and

[14]every exergaming session (T1 to T6).

clinical inference are also presented. This section also presents the results and qualitative analysis of the open-ended evaluation.

3.4 Results

3.4.1 Reliability of measurement scales

Table 3.3 shows the alpha coefficient values of the reliability analysis. The subscales of the Modified Technology Acceptance Questionnaire adapted from UTAUT (Venkatesh et al., 2003) demonstrated reliable internal consistency with an average Cronbach's α value of 0.90. The subscales of the Flow State Scale Jackson and Marsh (1996) also displayed satisfactory internal consistency with Cronbach's α with an average of 0.79. At all time points, the alpha values of the constructs were mostly highly satisfactory, exceeding the minimum alpha of 0.60 (Bland and Altman, 1996). The measurement scales were thus deemed reliable.

Table 3.3: Reliability of scale for Technology Acceptance and Flow measures

Outcome	measure	Initial (T0)	T1	T2	T3	T4	T5	T6	Average
UTAUT	Performance expectancy (PE)	0.91	0.92	0.95	0.95	0.91	0.95	0.97	0.94
	Effort expectancy (EE)	0.84	0.90	0.91	0.93	0.92	0.97	0.94	0.92
	Social influence (SI)	0.97	0.98	0.99	0.97	0.99	0.97	0.99	0.98
	Facilitating conditions (FC)	0.66	0.84	0.79	0.94	0.93	0.89	0.89	0.85
	Self-efficacy (SE)	0.82	0.83	0.81	0.83	0.51	0.77	0.64	0.75
	Behavioural intention (BI)	0.96	0.99	0.99	0.99	0.98	0.99	0.99	0.98
	Average	0.86	0.91	0.91	0.94	0.87	0.93	0.90	0.90
Flow	Autotelic experience (ENJY)		0.54	0.83	0.91	0.78	0.84	0.90	0.80
	Clear goals (GOAL)		0.60	0.72	0.86	0.86	0.82	0.88	0.79
	Challenge-skill-balance (CHAL)		0.70	0.80	0.84	0.82	0.88	0.81	0.81
	Concentration on task (CONC)		0.67	0.75	0.84	0.88	0.70	0.71	0.76
	Paradox of control (CONT)		0.86	0.70	0.92	0.81	0.83	0.87	0.83
	Unambiguous feedback (FDBK)		0.83	0.78	0.87	0.84	0.81	0.75	0.81
	Action-awareness-merging (ACT)		0.80	0.82	0.88	0.87	0.78	0.72	0.81
	Tranformation of time (TRAN)		0.57	0.65	0.86	0.82	0.89	0.87	0.78
	Loss of self-consciousness (LOSS)		0.67	0.69	0.84	0.82	0.78	0.74	0.76
	Average		0.69	0.75	0.87	0.83	0.81	0.81	0.79
	Overall average		0.78	0.81	0.90	0.85	0.86	0.85	0.84

Note: Greyed cells are not applicable.

3.4.2 Descriptive statistics of outcome measures

The means and standard deviations of outcome measures (i.e. variables of technology acceptance, flow experience, and perceived mental and physical effort) from the initial (T0) to the sixth exercise session (T6) are presented at Table 3.4. All measures of technology acceptance and flow demonstrated increases from the initial score although there were slight fluctuations in scores between the exercise sessions. This was the same for measures of Flow except that paradox of control (CONT) and loss of self-consciousness (LOSS) showed a gradual increase of scores from the first exercise session to completion. Scores of perceived physical exertion (BORG) also showed a gradual increase from 11.48 (deemed "fairly light") at T1 to 12.61 "somewhat hard") at T6 despite a slight fluctuation at T4. Perceived mental effort scores, however, remained fairly consistent at the "rather much effort" levels of the SMEQ, although 57.89 was scored at T1 compared to a slight decrease at 57.27 at T6.

Table 3.4: Mean and standard deviation of outcome measures over time

Outcome measure	Initial (T0)		T1		T2		T3		T4		T5		T6	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
UTAUT														
PE	4.31	1.22	5.52	1.31	5.30	1.50	5.51	1.46	5.49	1.41	5.27	1.70	5.61	1.59
EE	4.22	1.05	5.54	0.97	5.40	1.00	5.50	1.18	5.46	1.33	5.52	1.43	5.92	0.99
SI	4.16	1.67	4.93	1.46	4.89	1.61	4.87	1.64	4.77	1.76	4.93	1.76	5.18	1.75
FC	4.73	1.25	6.14	1.10	6.20	0.84	6.18	0.99	5.73	1.40	5.93	1.18	6.25	0.75
SE	4.29	1.16	5.07	1.16	5.23	0.99	5.04	1.18	5.11	0.90	5.29	1.02	5.63	0.89
BI	4.70	1.26	5.42	1.55	5.36	1.48	5.14	1.92	5.26	1.91	5.36	1.79	5.69	1.68
Flow														
ENJY			4.12	0.48	4.02	0.84	4.21	0.81	4.30	0.61	4.29	0.63	4.41	0.71
GOAL			3.82	0.50	3.93	0.58	4.28	0.64	4.23	0.63	4.28	0.56	4.34	0.65
CHAL			3.98	0.70	3.73	0.77	3.92	0.69	3.88	0.62	4.08	0.69	4.14	0.65
CONC			3.93	0.69	3.82	0.67	4.18	0.61	4.08	0.69	3.98	0.61	4.21	0.48
CONT			3.63	0.90	3.63	0.74	3.68	0.90	3.76	0.75	3.80	0.73	3.85	0.78
FDBK			3.79	0.69	3.63	0.70	3.91	0.75	3.90	0.66	3.97	0.64	4.14	0.58
ACT			3.60	0.80	3.54	0.84	3.68	0.80	3.67	0.73	3.70	0.72	3.86	0.67
TRAN			3.68	0.68	3.72	0.76	3.73	0.87	3.68	0.80	3.81	0.96	3.86	0.88
LOSS			3.74	0.63	3.89	0.69	4.14	0.66	4.24	0.58	4.27	0.55	4.49	0.44
Perceived effort														
BORG			11.48	1.49	12.02	1.59	12.23	1.24	11.95	1.71	12.58	1.25	12.61	1.26
SMEQ			57.89	11.67	56.64	13.80	55.36	12.07	57.11	12.93	57.29	12.90	59.27	14.75

Note: Greyed cells are not applicable. PE = performance expectancy. EE = effort expectancy. SI = social influence. FC = facilitating conditions. SE = self efficacy. BI = behavioural intention. ENJY = autotelic experience. GOAL = clear goals. CHAL = challenge-skill-balance. CONC = concentration. CONT = paradox of control. FDBK = unambiguous feedback. ACT = action-awareness-merging. TRAN = transformation of time. LOSS = loss of self-consciousness. BORG = perceived physical effort. SMEQ = subjective mental effort.

3.4.3 Analysis of variance (ANOVA)

Repeated measures one-way ANOVA was used to analyse the changes in variables of technology acceptance for all time points, and flow experience, and perceived physical and mental effort from T1 to T6. Table 3.5 presents the summary of the analysis of variance. The analysis revealed a significant overall improvement in all technology acceptance measures upon completion of the exercise sessions. However, not all of the flow measures showed significant changes. Repeated measures ANOVA confirmed significant improvements in autotelic experience, clear goals, challenge-skill-balance, concentration at task, unambiguous feedback and loss of self-consciousness. No significant differences were found in paradox of control, action-awareness-merging and transformation of time. The measure of perceived physical exertion was found to significantly increase over time while changes in perceived mental effort were not significant.

Table 3.5: Summary of analysis of variance

Outcome measure	SS		df		MS		F	p	ε^2
	Time	Error (Time)	Time	Error (Time)	Time	Error (Time)			
UTAUT									
Performance expectancy (PE)	[a]33.66	113.06	2.94	79.47	11.44	1.42	8.04	<.001	0.07
Effort expectancy (EE)	[a]47.36	104.89	3.70	99.77	12.82	1.05	12.19	<.001	0.16
Social influence (SI)	[a]16.71	135.38	3.11	84.05	5.37	1.61	3.33	<.05	0.07
Facilitation conditions (FC)	[a]48.64	108.86	3.43	92.64	14.18	1.18	12.06	<.001	0.27
Self-efficacy (SE)	[a]27.73	106.48	6.00	162.00	6.68	0.95	7.03	<.001	0.18
Behavioural intention (BI)	[a]15.65	119.29	3.10	83.59	5.06	1.43	3.54	<.05	0.03
Flow									
Autotelic experience (ENJY)	[a]2.78	25.15	2.51	67.77	1.11	0.37	2.98	<.05	0.07
Clear goals (GOAL)	[a]6.49	18.54	2.95	79.67	2.20	0.23	9.45	<.001	0.10
Challenge-skill-balance (CHAL)	[a]3.02	19.97	3.38	91.29	0.89	0.22	4.08	<.01	0.09
Concentration at task (CONC)	3.12	22.09	5.00	135.00	0.62	0.16	3.81	<.01	0.09
Paradox of control (CONT)	[a]1.20	28.29	3.44	92.93	0.35	0.30	1.15	NS	0.02
Unambiguous feedback (FDBK)	4.22	22.14	5.00	135.00	0.84	0.16	5.15	<.001	0.05
Action-awareness-merging (ACT)	[a]1.58	18.01	3.48	94.03	0.46	0.19	2.37	NS	0.04
Transformation of time (TRAN)	[a]0.74	34.46	3.08	83.05	0.24	0.42	0.58	NS	0.01
Loss of self-consciousness (LOSS)	[a]10.34	23.46	3.53	95.41	2.93	0.25	11.90	<.001	0.15
Effort									
Perceived physical exertion (BORG)	[a]25.43	110.95	3.73	100.59	6.83	1.10	6.19	<.001	0.14
Perceived mental effort (SMEQ)	[a]237.22	12917.65	2.67	72.15	88.78	179.05	0.50	NS	0.004

Note: [a]Greenhouse-Geisser correction applied.

3.4.4 *t* tests, confidence intervals and clinical inference

Table 3.6 presents the summary of *t* tests, confidence intervals and clinical inference. Changes in acceptance scores were calculated as the mean difference between before and after participating in the exergaming sessions. Changes were also calculated for mean differences in flow scores, perceived physical exertion and perceived mental effort obtained between the first and last exergaming sessions. These scores were then compared using Student's *t* test with Bonferroni correction. Cohen's *d* was calculated to estimate the effect size of the comparison between the means.

There were significant differences in scores of all the technology acceptance measures and in six of the flow measures (autotelic experience, clear goals, concentration at task, unambiguous feedback, action-awareness-merging and loss of self-consciousness). No significant changes were found in challenge-skill-balance and transformation of time. Similar to the analysis by repeated-measures ANOVA, pre-and post-intervention differences in perceived physical exertion were significant. However, those of perceived mental effort were not.

As presented in table 3.6, technology acceptance measures showed chances of beneficial or substantially positive effects. Performance expectancy (PE) increased upon completion of the intervention (mean difference 1.30, 95% confidence interval 0.69 to 1.90, d = 0.82) from a baseline mean of 4.31(SD = 1.22). Based on a minimally important change of 0.61 (where the difference was 0.5SD of the baseline measure)[15], this

[15] Taking PE as an example, the standard deviation at baseline, T0 is 1.22, therefore 0.5SD is 0.61 (see Table 3.4 on page 93).

represented a high chance (98.5%) that the true change of PE measures scored by participants were substantially beneficial or positive. While there was a 1.5% chance that this increase in PE was indeed negligible or trivial, this effect was not shown to be negative (0%). This showed that there was a strong (positive or beneficial) effect in participants' perception that they would derive benefit from exergaming.

Effort expectancy (EE) (mean difference 1.70, 95% CI 1.10 to 2.30, d = 1.51) revealed the highest estimated beneficial effect (100%) from a baseline mean of 4.22 (SD = 1.05) based on a minimally important change of 0.52. Towards the end of the intervention, participants' perception of exercising in a virtual environment was that they were able to perform the exercises. Chances of the true value of EE scored by participants fell completely in the beneficial or substantially positive range of the CI values.

Social influence (SI) (mean difference 1.02, 95% CI 0.38 to 1.70, d = 0.62) showed an increase from a baseline mean of 4.16 (SD = 1.67). Based on a minimally important change of 0.84, the probability (% chances) that the true effect was beneficial/trivial/harmful obtained was 71.5/28.5/0.0 and the true effect of SI scored by participants was possibly beneficial. This meant that there was a difference in the social environment of which influenced participants to use the exergaming technology from the beginning to the end of the intervention, and that difference was possibly substantially positive. In other words, participants' social environment (e.g. family members or friends) did have an influence on them in relation to exercising in the virtual environment throughout the intervention.

For facilitation conditions (FC), the mean effect of the exergaming intervention was an increase of 1.52 (95% CI 1.00 to 2.00, d = 1.21) and the probability (% chances) that the true effect was beneficial/trivial/harmful was 99.9/0.1/0.0; the true effect of FC scored by participants was almost certainly beneficial. This showed a substantially positive increase in participants' competency in using the exergaming system to perform exercise.

Where self-efficacy (SE) (mean difference 1.34, 95% CI 0.84 to 1.80, d = 1.03) was concerned, again the probability (% chances) that the true effect was beneficial/trivial/ harmful was 99.8/0.2/0.0; the true effect of SE scored by participants was likely to be almost certainly beneficial. This showed a likelihood that participants felt more confident of using the exergaming system for exercise at the end of the intervention.

The analysis of clinical inference also revealed that behavioural intention (BI) (mean difference 0.99, 95% CI 0.40 to 1.60, d = 0.65) showed a favourable percentage of chances that the true effect was beneficial/trivial/harmful at 88.8/11.2/0.0. This showed that a substantially positive effect in BI; a likely possibility that participants would intend to use the exergaming technology in future if it were readily made available.

For flow measures, the highest probability (% chances) that the true effect fell within the region of benefit was found in clear goals (GOAL) (mean difference 0.52, 95% CI 0.26 to 0.78, d = 0.77) and loss of self-consciousness (LOSS) (mean difference 0.75, 95% CI 0.48 to 1.00, d = 1.08). For GOAL, the percentage of chances of the true effect being beneficial/trivial/harmful was 97.8/2.2/0.0. The percentage of chances of the true effect being beneficial/trivial/harmful for LOSS was 99.8/0.2/0.0. This showed a largely beneficial effect in the increases in GOAL and LOSS scored by the participants.

Trivial effects were found for other flow measures. For unambiguous feedback (FDBK) (mean difference 0.35, 95% CI 0.09 to 0.61, d = 0.51), the percentage of chances of the true effect being beneficial/trivial/harmful was 50.0/50.0/0.0, representing chances that the effect was possibly trivial. Concentration at task (CONC) (mean difference 0.28, 95% CI 0.05 to 0.51, d = 0.48) showed magnitudes being beneficial/trivial/harmful that fell in the region of "very likely trivial" at 26.7/73.3/0.0. Both challenge-skill-balance (CHAL) (mean difference 0.16, 95% CI -0.10 to 0.41, d = 0.24) and paradox of control (CONT) (mean difference 0.21, 95% CI -0.11 to 0.53, d = 0.25) showed magnitudes being beneficial/trivial/harmful that fell in the region of "probably trivial" at 6.8/93.2/0.0 and 6.9/93.1/0.0. Possibly trivial effects were found for action-awareness-merging (ACT) (mean difference 0.26, 95% CI 0.02 to 0.50, d = 0.41) and transformation of time (TRAN) (mean difference 0.18, 95% CI -0.17 to 0.53, d = 0.20) where percentage of chances of the effect being beneficial/trivial/harmful was 12.4/87.6/0.0 and 18.0/81.7/0.3.

A possibly beneficial effect was found for perceived physical exertion (mean difference 1.13, 95% CI 0.55 to 1.70, d = 0.75) with the percentage of chances of the true effect being beneficial/trivial/harmful at 67.5/32.5/0.0. In contrast, the true effect of subjective mental effort (SMEQ) (mean difference 1.40, 95% CI -6.10 to 8.90, d = 0.07) invested during the intervention was found to fall in the region of "very likely trivial" with the values of % chances being beneficial/trivial/harmful at 11.8/85.3/2.9.

In conclusion, although the analysis revealed that many measures showed a substantial beneficial effect and some measures showed percentage of chances that the true effects were trivial, there was no evidence of any negative effect in any of the measures.

Table 3.6: Summary of *t* tests, confidence intervals and clinical inference

Outcome measure	Mean difference	Minimum magnitude of change	Expressed outcome with 95% confidence interval		*t*(27)	*p*	*d*	Percentage of chances that the true value of the effect statistic is		
			LL	UL				beneficial or substantially positive	negligible or trivial	harmful or substantially negative
UTAUT										
PE	1.30	0.61	0.69	1.90	4.34	<.001	0.82	98.5	1.5	0.0
EE	1.70	0.52	1.10	2.30	7.97	<.001	1.51	100.0	0.0	0.0
SI	1.02	0.84	0.38	1.70	3.26	0.003	0.62	71.5	28.5	0.0
FC	1.52	0.63	1.00	2.00	6.42	<.001	1.21	99.9	0.1	0.0
SE	1.34	0.58	0.84	1.80	5.47	<.001	1.03	99.8	0.2	0.0
BI	0.99	0.63	0.40	1.60	3.47	0.002	0.65	88.8	11.2	0.0
Flow										
ENJY	0.29	0.24	0.09	0.49	3.01	0.006	0.57	69.4	30.6	0.0
GOAL	0.52	0.25	0.26	0.78	4.05	<.001	0.77	97.8	2.2	0.0
CHAL	0.16	0.35	-0.10	0.41	1.30	0.206	0.24	6.8	93.2	0.0
CONC	0.28	0.35	0.05	0.51	2.52	0.018	0.48	26.7	73.3	0.0
CONT	0.21	0.45	-0.11	0.53	1.34	0.193	0.25	6.9	93.1	0.0
FDBK	0.35	0.35	0.09	0.61	2.72	0.011	0.51	50.0	50.0	0.0
ACT	0.26	0.40	0.02	0.50	2.19	0.037	0.41	12.4	87.6	0.0
TRAN	0.18	0.34	-0.17	0.53	1.05	0.304	0.20	18.0	81.7	0.3
LOSS	0.75	0.32	0.48	1.00	5.69	<.001	1.08	99.8	0.2	0.0
Perceived effort										
BORG	1.13	1.00	0.55	1.70	3.99	<.001	0.75	67.5	32.5	0.0
SMEQ	1.40	5.84	-6.10	8.90	0.38	0.705	0.07	11.8	85.3	2.9

Note. PE = performance expectancy. EE = effort expectancy. SI = social influence. FC = facilitating conditions. SE = self-efficacy. BI = behavioural intention. ENJY = autotelic experience. GOAL = clear goals. CHAL = challenge-skill-balance. CONC = concentration. CONT = paradox of control. FDBK = unambiguous feedback. ACT = action-awareness-merging. TRAN = transformation of time. LOSS = loss of self-consciousness. BORG = perceived physical effort. SMEQ = subjective mental effort.

3.4.5 Open-ended evaluation: Content analysis

Content analysis identified ten themes generated within responses to the open-ended evaluation “What did you think of the session?” posed to participants upon completion of every exercise session (see Table 3.7). The most frequently occurring theme was enjoyment, followed by physically challenging, mentally challenging, self-improvement, perceived benefits of exergaming, adapting to VR, feeling of ease, behavioural intention to use, limitation of exergaming technology and loss of time consciousness. Examples of excerpts of the responses are presented in Appendix E at page 310. The frequency of themes generated from multiple responses is presented at Table 3.8 on page 104.

3.4.6 Interrater reliability

Multiple responses to the open-ended evaluation were coded by the author and two independent raters. The coding system was explained to the independent raters (see Table D.2 at page 303). The coders also discussed the research question, the data to be coded and the rules of interpretation. The coding protocol was tested by coding two records of data collectively. Following this, the researchers independently coded the rest of the data. The numerical κ values in rating agreement (Landis and Koch, 1977) are presented earlier at Table 3.2 on page 88. Interrater reliability (Hayes and Krippendorf, 2007; Krippendorf, 2004) was assessed using Fleiss' kappa (Fleiss, 1971) via ReCal 3, an online interrater reliability service (Freelon, 2010*b*). Table 3.9 presents the κ values obtained from the coded ratings.

Table 3.7: The description of themes derived from content analysis

	Theme	Description
1	Enjoyment	Liked the idea of seeing their image on the television screen Happy, rewarding experience Good fun Interesting and amusing Relaxed, able to interact with the virtual environment without being concerned about "getting it right" with the system
2	Mentally challenging	Baffling to get the right moves
3	Physically challenging	Especially on bending or crouching "Hard on the old knees!"
4	Loss of time consciousness	Lost track of time
5	Self-improvement	Feeling more confident Feeling improvement in performance
6	Feeling of ease	Did not feel tired at all There was no pressure
7	Adapting to VR	Finding ways to score in the games Trying out different movements to get a higher score Anticipating where the ball will "fall" Able to predict progress in the game although not always accurate
8	Limitations of exergaming technology	Noticed lapses in motion capture
9	Perceived benefits of exergaming	Perceptions that exergaming may be more enjoyable played in a group rather than individually Perceptions that exergaming is psychologically beneficial
10	Behavioural intention to use	Would recommend it to other people Would continue if it were readily available

Table 3.8: Frequency of themes generated from multiple responses

	Theme & Description	T1	T2	T3	T4	T5	T6	Ave
1	Enjoyment							
	Yes (enjoyable)	28	25	23	23	24	23	24.33
	No (slightly frustrating, baffling)	0	2	1	1	1	1	1.00
2	Mentally challenging							
	Yes (needs to concentrate)	8	7	7	10	6	7	7.50
	No (little effort needed, easy)	1	1	0	0	0	0	0.33
3	Physically challenging							
	Yes	5	4	10	10	11	11	8.50
	No (not difficult to do)	1	0	0	0	0	1	0.33
4	Loss of time consciousness							
	Yes (time passed by very quickly)	0	1	2	1	1	4	1.50
	No (didn't think about it at all)	0	0	0	0	0	0	0.00
5	Self improvement							
	Yes (getting better, more skilful, more confident)	1	10	6	6	6	6	5.83
	No (getting worse or none)	0	2	1	0	2	1	1.00
6	Feeling of ease							
	Yes (relaxed, no strain)	3	7	4	2	1	0	2.83
	No (muscles aching, tiring)	0	0	0	2	0	0	0.33
7	Adapting to VR							
	Yes(adjusting to the spatial perspective, working out ways to win)	2	7	2	1	5	3	3.33
	No (still not used to it)	1	1	1	0	0	1	0.67
8	Limitation of exergaming technology							
	Yes (noticed the lapse in motion capture)	1	2	1	3	1	3	1.83
	No (did not notice any lapse in motion capture)	0	0	0	0	0	0	0.00
9	Perceived benefits of exergaming							
	Psychological and/or physical benefit	6	2	3	2	3	6	3.67
	Beneficial for indoor use	1	0	0	0	0	1	0.33
10	Behavioural intention to use							
	Yes (would recommend/use)	7	3	2	0	1	3	2.67
	No (not likely to use in future)	1	0	1	0	0	1	0.50

Table 3.9: Inter-coder reliability of multiple responses

Theme	T1	T2	T3	T4	T5	T6	Ave
Enjoyment	0.28	0.22	0.64	0.42	0.60	0.69	0.47
Mentally challenging	0.50	0.43	0.43	0.85	0.77	0.65	0.60
Physically challenging	0.70	0.32	0.43	0.53	0.44	0.41	0.47
Loss of time consciousness	*	0.74	1.00	1.00	1.00	0.84	0.92
Self improvement	0.06	0.25	0.05	0.32	0.17	0.17	0.17
Feeling of ease	0.33	0.15	0.09	0.19	0.04	0.21	0.17
Adapting to VR	0.23	0.13	0.09	-0.04	0.33	-0.08	0.11
Limitations of exergaming technology	-0.02	0.31	-0.01	0.09	1.00	0.46	0.31
Perceived benefits of exergaming	0.16	0.45	0.72	0.58	0.45	0.37	0.45
Behavioural intention to use	0.45	0.59	0.42	-0.01	0.79	0.58	0.47

*: Undefined. Fleiss' kappa could not be calculated for this variable due to invariant values
Ave : The average value

The average kappa values were within the range of almost perfect agreement for loss of time consciousness and substantial agreement for mentally challenging. Kappa values showing moderate agreement were obtained for the following themes: enjoyment, physically challenging, perceived benefits of exergaming and behavioural intention to use. The average kappa value for limitations of exergaming technology was 0.31 (range -0.01 and 1.00) within the region of fair agreement. Three other themes showed poor kappa values: self-improvement, feeling of ease and adapting to VR.

An undefined κ value was obtained for loss of time-consciousness at T1 because the coding either showed 100% agreement between the coders or selected the same code value for every unit of analysis. When this happens, theoretically the concept of reliability does not hold here because there is no covariation (Krippendorf, 2004).

Subsequently, the coding was revised to remove possible outliers. Interrater reliability was assessed again. Because the coders had reached unanimous agreement and agreed that there were no other themes present in the data, percent agreement was presented as an alternative indicator of interrater reliability (Freelon, 2010*a*). Table 3.10 shows reliability in κ values and percent agreement.

Upon revision of the coding data, there was an improvement in kappa values ranging from 0.43 to 0.92 and the average pairwise percentage agreement for all themes exceeded 80% (range 87.70 to 99.21). The kappa value for loss of time consciousness remained the same while κ values obtained for mentally challenging, physically challenging, perceived benefits of exergaming and behavioural intention to use were within the region of substantial agreement. Moderate agreement values of kappa were obtained for the rest of the themes: adapting to VR, self improvement, feeling of ease, limitations of exergaming technology and enjoyment.

Table 3.10: Interrater reliability of multiple responses presented with average pairwise percent agreement as an alternative indicator of reliability

Theme	T1	AP%	T2	AP%	T3	AP%	T4	AP%	T5	AP%	T6	AP%	Ave κ	Ave %
Enjoyment	0.34	85.71	0.62	88.10	0.64	88.10	0.63	92.86	0.60	88.10	0.69	91.67	0.59	89.09
Mentally challenging	0.69	85.33	0.66	90.48	0.67	88.10	0.85	92.86	0.77	92.86	0.65	88.10	0.71	89.62
Physically challenging	0.70	90.48	0.63	92.86	0.66	85.71	0.77	90.48	0.71	88.10	0.50	78.57	0.66	87.70
Loss of time consciousness	*	100.00	0.74	97.62	1.00	100.00	1.00	100.00	1.00	100.00	0.84	97.62	0.92	99.21
Self improvement	0.24	96.43	0.65	84.52	0.39	89.29	0.51	86.91	0.43	88.10	0.46	92.86	0.45	89.68
Feeling of ease	0.58	95.24	0.54	92.86	0.49	97.62	0.48	95.24	0.49	97.62	0.49	97.62	0.51	96.03
Adapting to VR	0.47	92.86	0.46	90.48	0.26	91.67	*	100.00	0.54	92.86	*	100.00	0.43	94.64
Limitations of exergaming technology	*	100.00	0.49	97.62	*	100.00	0.24	96.43	1.00	100.00	0.46	92.86	0.55	97.82
Perceived benefits of exergaming	0.37	85.71	0.79	97.62	0.72	95.24	1.00	100.00	0.79	97.62	0.63	92.86	0.72	94.84
Behavioural intention to use	0.63	85.71	0.69	95.24	1.00	100.00	*	100.00	0.79	97.62	0.58	88.10	0.74	94.44

* : Undefined; Fleiss' kappa could not be calculated for this variable due to invariant values.
AP% : average pairwise percentage agreement.
Ave κ : overall average value of kappa values.
Ave % : overall average value of AP%.

3.4.7 Illustrations of themes

Enjoyment

Participants reported that once they made the first attempt to exercise using the exergaming system, they found the exercise experience to be engaging and enjoyable. It seemed that most could perform the required physical movements to interact with the virtual objects within the virtual environment.

> "That was good fun! When is the next session?" (female, age 61 at T1)

There were also instances when things did not go as expected. Participants were either missing hits or not getting results as desired.

> "Less confusing with regard to intentions but still difficulty with amounts of movement required to give appropriate movement of on-screen persona. Slightly frustrating." (male, age 58 at T3)

Physically challenging

Some participants reported that performing exercise with the exergaming system was sufficient to work up a sweat.

> "...good exercise, will be glad to do it again. I am really sweating and hot right now." (female, age 64 at T1)

There was also an enthusiastic few who exerted themselves further in the exergaming sessions.

> “Think I overstepped the mark on one or two occasions. Should think like a 68-year old or maybe I am too fast for my own good.” (female, age 69 at T5).

Mentally challenging

Participants also reported that they had to concentrate on the exergaming system in order to interact with the virtual objects.

> “Good, becoming harder. You concentrate more." (female, age 66 at T3)

Participants also felt that they had to think about which direction to go, which part of the body to move and *when* to make these movements.

> “it made me work harder and had to concentrate more. It also helped me to get my balance." (female, age 64 at T4).

Self-improvement

Participants also expressed an expectation of making progress in their exercise.

> “I think I could improve with a bit of practice." (Male, age 69 at T4).

But there were also reports of not being able to keep up with the momentum.

> “didn’t do as well as yesterday at the start of the session!” (female, age 65 at T2)

Perceived benefits of exergaming

Participants thought that “exercising with a computer” was beneficial in a number of ways. It could be done as a social activity, help individuals with a wide range of disabilities, and serve as a form of indoor exercise.

> “I feel these games will be very beneficial to people who have disabilities of varying degrees. Apart from the physical attributes, the achievement and enjoyable satisfaction will be of psychological benefit." (female, age 62 at T6)

> “The exercise programme is really good for people of all abilities it should be taken in to health centres as well as hospital. It gives you a sense of well-being and confidence." (female, age 54 at T6)

> “Nonetheless, I think the system would be useful for people who like to exercise alone or at home.” (male, age 64 at T6)

Adapting to exergaming technology

Some participants were able to adjust to the virtual environment using the visual feedback provided by the system while simultaneously making physical movements in their actual position.

> “Getting used to the screen. Not so difficult this time still very interesting and amusing.” (female, age 76 at T2)

A few participants felt the challenge of having to gauge the amount of actual physical movement to coincide with the visual feedback shown on the TV screen.

> “Again I find it difficult to judge where my hands were when playing the volleyball. I did not manage to get a consistent hit.” Female, age 54 (T6)

Feeling of ease

Interestingly, some participants found the exercise experience to be relaxing.

> “I found the session quite rewarding. It was light-hearted and you were made to feel at ease. No pressure.” (female, age 60 at T2)

While others thought it was not.

> “Volleyball hard to do, cannot seem to serve ball.” (female, age 50 at T4)

Behavioural intention to use

Some participants expressed intention to use the exergaming system for exercise if it were readily available.

> “...I wouldn’t go to the gym but I would exercise using one of these." (female, age 64 at T2)

One participant however, preferred conventional group exercises. Although he found the exercise experience to be enjoyable, he did not express positive intentions to continue exergaming.

"I do not feel I would use a computer system for exercise." (male, age 64 at T6)

Limitation of exergaming technology

Contrary to stereotypes of older people as not being tech-savvy[16] or able to play video games, some participants were quick to point out limitations in the exergaming system. One of this was the time lapse in motion capture[17]. Another was the failure of the system[18] to detect the full body image of the participant.

"..some movement doesn't seem to transfer onto screen as anticipated." (male, age 58 at T4)

Loss of time consciousness

Some participants reported not being aware of time flow while exercising in the virtual environment. Most responses about time awareness suggested that participants did not think about time during the exercise experience or changed their behaviour according to the time flow.

"...the morning passed really quickly..." (female, age 54 at T3)

[16] label given to young people assumed to be more competent in managing and living with new technologies (Dolezalek, 2003).

[17] This problem was due to calibration errors in the IREX™.

[18] Fortunately, the exergaming system was in working condition most of the time.

3.4.8 Descriptive statistics of the themes

Frequency of themes generated from multiple responses is presented at Table 3.8 on page 104. Enjoyment was most evident in participant responses, followed by mentally and physically challenging throughout the intervention. Loss of time consciousness was present in one response from the second session (T2) onwards, and present in 4 responses at T6. This implied an increased sense of time loss among participants towards the end of the intervention. This was similar for self-improvement where it was present in only one response at T1 but found in 6 responses at T6. At T6 only one negative response was found, implying no improvement in negotiating the exergaming exercises.

At all time points, there were responses pertaining to adapting to exergaming technology. Adaptation to exergaming technology here suggested that participants were able to gauge the distance of physical movement to coincide with the movement of their image in the virtual environment, enabling a smooth interaction with virtual objects. Responses implying difficulty in adapting to the virtual environment were present in data from 3 participants at T1, T2, T3 and T6.

Overall, feeling of ease was present in 17 responses from 11 participants from T1 to T5. At T4, 2 participants noted physical strain in their responses. Perceived benefits of exergaming was present in a total of 24 responses from 13 participants throughout the intervention. Perceived benefits for indoor use was found in responses from 2 participants. Perceived psychological benefits were present in 22 responses from 13 participants. Behavioural intention to use exergaming was also present in 15 responses from

13 participants from T1 to T3 and T5 to T6. Only one participant responded negative for behavioural intention.

3.4.9 Outcome measures in comparison with the theme ‘Enjoyment’

Because enjoyment was the most frequently described theme generated through content analysis, a comparison was made between enjoyment and the quantitative outcome measures to see if there were any differences in scores in relation to enjoyment. Data for the outcome measures were selected following participants’ responses to the open-ended evaluation at all time points. The means and standard deviations of outcome measures in relation to the subthemes of ‘Enjoyment’ are presented at Table 3.11.

The comparison shows that all scores of technology acceptance measures (PE, EE, SI, SE and BI) except facilitation conditions (FC) were higher whenever enjoyment was reported than expressions implying “slightly frustrating, baffling”. In contrast, perceived physical exertion (BORG) and subjective mental effort (SMEQ), scores were higher whenever expressions implying “slightly frustrating, baffling” were present. There was no clear distinction, however, for flow measures whenever both subthemes of “Enjoyment” were reported.

Table 3.11: Means and standard deviations of outcome measures in comparison with subthemes of Enjoyment

Outcome measure	“Enjoyable”	“slightly frustrating, baffling”
Technology Acceptance measures		
Performance expectancy (PE)	5.47 (1.46)	4.73 (2.15)
Effort expectancy (EE)	5.56 (1.16)	5.45 (1.04)
Social influence (SI)	4.93 (1.65)	4.70 (1.72)
Facilitation conditions (FC)	6.07 (1.08)	6.20 (0.84)
Self-efficacy (SE)	5.23 (1.04)	5.10 (1.08)
Behavioural intention (BI)	5.41 (1.68)	4.00 (2.32)
Flow measures		
Autotelic experience (ENJY)	4.24 (0.69)	3.80 (0.87)
Clear goals (GOAL)	4.15 (0.62)	4.10 (0.58)
Challenge-skill-balance (CHAL)	3.96 (0.68)	3.95 (0.96)
Concentration at task (CONC)	4.02 (0.64)	4.30 (0.41)
Paradox of control (CONT)	3.72 (0.79)	3.75 (0.92)
Unambiguous feedback (FDBK)	3.88 (0.68)	4.10 (0.63)
Action-awareness-merging (ACT)	3.68 (0.73)	3.40 (1.52)
Transformation of time (TRAN)	3.74 (0.82)	3.85 (1.01)
Loss of self-consciousness (LOSS)	4.13 (0.64)	4.20 (0.54)
Perceived physical exertion (BORG)	12.13 (1.48)	12.88 (0.74)
Perceived mental effort (SMEQ)	56.99 (12.92)	66.20 (10.35)

3.4.10 Moderated multiple regression

Model 1

Tests of H_a – H_e. Multiple regression results are presented at Table 3.12. When only direct effects were regressed, the model was significant at all time points. Adjusted R^2 values ranged from .53 to .88. When interaction terms were included, these values increased from .74 to .96. Values for R^2 change ranged from .03 to .13. However, the *F*-values for R^2 change did not significantly differ, thus indicating that the inclusion of interaction terms did not improve the model.

Most of the time, performance expectancy (PE) was the strongest predictor of behavioural intention (BI). At T0 when participants rated the technology acceptance variables based on their perceived expectations (i.e. before trying the exergaming system), there was a significant effect of PE when the main effects were included with the interaction effects. At T1, the influence of PE was signficant when only main effects were regressed. At T2, the influence remained when other main effects were held constant, and also when interaction effects were included. The pattern of influence was more or less the same over time, with a significant influence of PE on BI at the end of the intervention for both regressions.

To test the R^2 changes in the model between time-points, the *F*-values for the mean-squared residuals were calculated. From the calculations (presented in Appendix F.23 on page 331), there was a significant increase in R^2 from the initial (T0) to the last session (T6) when the dependent variable BI was regressed against only main effects

(PE, EE, SI, AGE and GDR), $F_{22,22}$ = 2.22, $p < .05$. When interaction terms were included in the equation, there was a significant difference in R^2 increase from between T0 to T6, $F_{15,15}$ = 3.28, $p < .05$.

Table 3.12: Multiple-regression analysis of the modified Technology Acceptance model

	Initial (T0)		T1		T2		T3	
	D only	D+I	D only	D+I	D only	D+I	D only	D+I
R^2	***0.61	0.74	***0.68	0.81	***0.77	0.83	***0.73	0.76
Adjusted R^2	0.53	0.53	0.60	0.66	0.71	0.69	0.67	0.57
R^2 change		0.13		0.14		0.06		0.03
Constant	***4.54	***5.25	***5.46	***5.38	***5.50	***6.18	***5.23	***4.68
Performance expectancy (PE)	0.40	*1.06	**0.91	0.56	***0.97	*1.14	***1.32	0.68
Effort expectancy (EE)	0.04	1.07	-0.19	0.05	-0.52	-0.86	-0.30	0.39
Social influence (SI)	0.29	1.17	0.18	0.43	0.24	0.25	-0.10	-0.05
Age(AGE)	0.02	-0.13	-0.03	0.01	-0.03	-0.14	*-0.07	0.11
Gender (GDR)	0.27	-0.49	-0.07	0.17	-0.25	-0.73	-0.16	0.51
PE X GDR		-0.46		0.23		-0.13		0.31
EE X GDR		-1.09		-0.14		0.73		-0.48
SI X GDR		-1.01		-0.32		-0.14		-0.04
PE X AGE		-0.05		-0.06		-0.06		0.06
EE X AGE		-0.01		0.08		0.17		-0.02
SI X AGE		0.02		0.02		-0.06		-0.02
AGE X GDR		0.12		-0.05		0.13		-0.19

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Note: D ONLY: Direct effects only; D+I: Direct effects and interaction terms.
Blank cells are not applicable for the specific column.
*p <0.05. **p <0.01. ***p <0.001.

Table 3.12: Model 1 continued

Continued from the previous page	T4		T5		T6	
	D only	D+1	D only	D+1	D only	D+1
R^2	***0.85	0.88	***0.73	0.81	***0.90	0.96
Adjusted R^2	0.81	0.78	0.67	0.65	0.88	0.92
R^2 change		0.03		0.08		0.05
Constant	***5.32	***5.22	***5.14	***5.30	***5.77	***5.77
Performance expectancy (PE)	***0.98	**1.20	*1.03	0.81	***1.15	*0.92
Effort expectancy (EE)	*0.53	-0.05	-0.13	0.01	-0.16	-0.28
Social influence (SI)	-0.16	-0.05	-0.09	0.07	-0.10	-0.11
Age (AGE)	-0.01	0.02	0.04	0.05	-0.01	0.07
Gender (GDR)	-0.10	0.18	0.38	0.41	-0.13	0.26
PE X GDR		0.23		0.20		-0.44
EE X GDR		0.16		-0.21		*0.79
SI X GDR		-0.29		-0.33		0.04
PE X AGE		0.01		0.06		0.01
EE X AGE		0.07		-0.01		0.04
SI X AGE		-0.05		-0.07		-0.01
AGE X GDR		-0.04		0.00		*-0.10

Note: D ONLY: Direct effects only; D+I: Direct effects and interaction terms.
Blank cells are not applicable for the specific column.
*p <0.05. **p <0.01. ***p <0.001.

Model 2

Tests of $H_f - H_g$. In this model simulating Davis and Venkatesh (2004) (shown earlier at Figure 3.3 on page 72), the independent variables were entered into the regression equation in three successive steps. In the first step, (1) BI from the previous session, (2) the main effects (PE, EE, SI, AGE and GDR), and (3) the two-way interaction terms (BI x GDR and BI x AGE), were entered, respectively. Multiple-regression results are presented at Table 3.13.

The first step of the multiple regression showed that previous BI was positively associated with BI at all time points, supporting the influence of previous behaviour as an important determinant of future behaviour (Norman and Smith, 1995; Ouellete and Wood, 1998; Venkatesh and Davis, 2000; Davis and Venkatesh, 2004). When main effects were included in the equation, the influence of previous BI occurred from T2 onwards. At T5, age and gender significantly predicted BI.

When interaction terms were included in the equation, the pattern of prediction of BI by the previous BI shown in the first regression step was not clear. Again PE and the previous BI were the only independent variables which significantly predicted BI, but this was only at T2, T3, T4 and T6. At T5, two significant predictors were previous BI and GDR. Although the multivariate tests were indeed significant, the two-way interaction terms did not contribute significantly to the prediction of BI. The coefficient of determination from T4 to T6 showed the same values with minimal changes in R^2 that were also not statistically significant, indicating that the inclusion of the interaction terms did little to account for the variance in BI.

Nevertheless, at T3, BI was significantly predicted by the previous BI (b = .86, t_{21} = 4.40, $p < .001$), and after controlling for the latter, the other variables (main effects as well as two-way interactions) did not account for any additional variance in the outcome (i.e. they became non-significant), behavioural intention to use exergaming. This is in support of Davis and Venkatesh (2004).

To test the R^2 changes in the model between time-points, the F-values for the mean-squared residuals were calculated. From the calculations (presented at Appendix F.24 on page 331), there was a significant change in R^2 from the first (T1) to the last session (T6) when the dependent variable BI was regressed against the previous BI and the main effects (PE, EE, SI, AGE and GDR), $F_{21,21}$ = 2.65, $p < .05$. When interaction terms were included in the equation, the difference in R^2 change from T1 to T6 approached significance, $F_{19,19}$ = 2.21, $p < .05$.

Table 3.13: Multiple-regression analysis of the modified Technology Acceptance model 2

	T1 (n=28)			T2 (n=28)			T3 (n=28)		
	D	D+I	D+II	D	D+I	D+II	D	D+I	D+II
R^2	***0.48	*0.70	*0.76	***0.50	**0.81	0.82	***0.82	***0.86	0.88
Adjusted R^2	0.46	0.61	0.66	0.48	0.75	0.74	0.81	0.82	0.82
R^2 change		*0.22	0.06		**0.31	0.01		0.04	0.02
Constant	***5.42	***5.52	***5.65	***5.36	***5.45	***5.45	***5.14	***5.17	***5.18
BI at T0	***0.86	0.32	0.43						
BI at T1				***0.67	†0.25	0.15			
BI at T2							***1.17	***0.86	**0.88
BI at T3									
BI at T4									
BI at T5									
Performance expectancy (PE)		**0.86	0.59		**0.77	**0.92		0.35	0.29
Effort expectancy (EE)		-0.23	0.03		-0.39	-0.52		0.09	0.12
Social influence (SI)		0.02	0.11		0.18	0.02		-0.07	-0.05
Age (AGE)		-0.04	-0.02		-0.03	-0.02		-0.03	-0.02
Gender (GDR)		-0.18	-0.24		-0.15	-0.22		-0.05	0.05
BI X GDR			-0.26			0.13			0.002
BI X AGE			-0.04			-0.004			0.02

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Note: D: Direct effect (BI at the previous time) only. D+I: Other predictors included. D+II: Two-way moderation included. Blank cells are not applicable for the specific column.
*p <0.05. **p <0.01. ***p <0.001. †: p = 0.054.

Table 3.13: Model 2 continued

Continued from the previous page	T4 (n=28)			T5 (n=28)			T6 (n=28)		
	D	D+I	D+II	D	D+I	D+II	D	D+I	D+II
R^2	***0.74	*0.89	0.91	***0.78	**0.90	0.91	***0.72	**0.90	0.91
Adjusted R^2	0.73	0.85	0.87	0.77	0.88	0.87	0.71	0.87	0.87
R^2 change		**0.14	0.02		**0.13	0.004		***0.18	0.01
Constant	***5.26	***5.39	***5.22	*1.00	*1.54	***5.12	***5.69	***5.77	***5.71
BI at T0									
BI at T1									
BI at T2									
BI at T3	***0.86	*0.40	0.30						
BI at T4				***0.83	***0.67	***0.73			
BI at T5							***0.80	0.02	0.03
Performance expectancy (PE)		***0.80	***1.05		-0.09	-0.24		***1.14	***1.24
Effort expectancy (EE)		0.13	-0.09		0.48	0.59		-0.17	-0.35
Social influence (SI)		-0.10	-0.10		0.01	0.02		-0.10	-0.09
Age (AGE)		-0.19	-0.01		*0.04	0.03		-0.01	-0.01
Gender (GDR)		-0.22	-0.07		**0.52	*0.49		-0.14	-0.16
BI X GDR			0.21			-0.08			0.09
BI X AGE			0.01			0.00			-0.002

Note: D: Direct effect (BI at the previous time) only. D+I: Other predictors included. D+II: Two-way moderation included.
Blank cells are not applicable for the specific column.
*p <0.05. **p <0.01. ***p <0.001.

Model 3

Test of H_h. In response to Model 2 (see page 120), this equation included not only the previous BI but also the preceding BIs measured in earlier sessions. The independent variables were entered into the regression equation in two successive steps. In the first step, (1) the previous BI and any BI that precedes the former, and (2) the main effects (PE, EE, SI, AGE and GDR). In the earlier models, the presence of two-way interactions in the equation were suggestive of multicollinearity (Aguinis, 1995; Blalock, 1963). Therefore, they were not included in Model 3. Table 3.14 summarises the results of the analysis from T1 to T6.

As expected, behavioural intention was well predicted by the previous BIs. Interestingly, at T3, the significant determinants were all the previous BIs. When these were held constant, the main effects did not explain any additional variance in BI. These results are in line with those presented earlier from Model 2 (see Table 3.13 on page 122) and accordingly, corroborate the observations of Davis and Venkatesh's (2004) user acceptance studies.

F-values of the residuals were calculated to verify the R^2 changes in the model. The calculations (presented at Appendix F.25 on page 332) show that there were significant differences in the R^2 changes from the first (T1) to the last (T6) session when the dependent variable BI was regressed against the previous BIs ($F_{26,21}$ = 2.83, $p < .05$), and also when main effects were included in the equation ($F_{21,16}$ = 4.97, $p < .001$).

Table 3.14: Model 3 (from T1 to T3)

	T1		T2		T3	
	D	D+1	D	D+1	D	D+1
R^2	***0.48	*0.70	0.50	**0.81	*0.87	*0.93
Adjusted R^2	0.46	0.61	0.46	0.74	0.85	0.90
R^2 change		*0.22		**0.31		*0.06
F	***23.81	***8.07	***12.37	***12.23	***53.52	***31.16
df	1,26	6,21	2,25	7,20	3,24	8,19
Constant	***5.42	***5.52	***5.36	***5.43	***5.14	***5.05
BI at T0	***0.86	0.32	0.003	-0.13	-0.18	*-0.39
BI at T1			**0.67	*0.31	**0.47	***0.62
BI at T2					***0.90	**0.50
BI at T3						
BI at T4						
BI at T5						
Performance expectancy (PE)		***0.86		**0.77		0.24
Effort expectancy (EE)		-0.23		-0.41		0.19
Social influence (SI)		0.02		0.21		0.10
Age (AGE)		-0.04		-0.02		0.02
Gender (GDR)		-0.18		-0.13		0.18

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Note: D: Main effect (BI from the previous times) only. D+1: All main effects.
Greyed out cells are not applicable for the specific column.
*p <.05. **p <.01. ***p <.001.

Table 3.14: Model 3 (from T4 to T6)

Continued from the previous page	T4		T5		T6	
	D	D+1	D	D+1	D	D+1
R^2	***0.79	*0.89	***0.86	**0.94	***0.87	**0.96
Adjusted R^2	0.75	0.83	0.82	0.90	0.84	0.93
R^2 change		*0.10		**0.08		**0.09
F	***21.34	***15.77	***26.32	***26.36	***23.96	***35.22
df	4,23	9,18	5,22	10,17	6,21	11,16
Constant	***5.26	***5.41	***5.36	***5.12	***5.69	***5.62
BI at T0	0.26	0.07	0.09	-0.06	0.05	-0.22
BI at T1	-0.27	-0.13	-0.14	-0.15	-0.05	0.21
BI at T2	0.42	0.04	-0.02	-0.07	0.35	0.25
BI at T3	*0.65	0.45	*0.60	*0.46	0.11	0.09
BI at T4			*0.37	**0.46	**0.48	0.19
BI at T5					0.01	*-0.48
Performance expectancy (PE)		**0.75		-0.10		***0.99
Effort expectancy (EE)		0.17		0.44		0.02
Social influence (SI)		-0.12		0.02		-0.08
Age		-0.02		*0.05		0.01
Gender		-0.25		*0.41		0.13

Note: D: Main effect (BI from the previous times) only. D+1: All main effects.
Greyed out cells are not applicable for the specific column.
*p <.05. **p <.01. ***p <.001.

3.5 Discussion and conclusion

This section discusses the findings from healthy older adults by answering the research questions (described earlier in Chapter 2 on page 57).

3.5.1 Are older people likely to accept exergaming in relation to its technology and use?

The current study found that the level of all measured constructs of technology acceptance increased over the course of the exergaming intervention, demonstrating a significant positive influence on not only older people's behavioural intention to use exergaming, but also their performance expectancy, effort expectancy and social influence in using the exergaming technology. Participants exercised with the exergaming system by making suitable body movements to interact with the virtual animations in the exergames (e.g. dodging electric eels and sharks in Sharkbait). Some exergame applications required the continous use of both upper- and lower limbs (e.g. soccer) and the major muscle groups (e.g. formula-racing and snowboarding). Exergaming was initially perceived as not difficult to do because of the freedom in range-of-movement without having to use external electronic devices (e.g. joysticks or head mounted displays). Over time, participants understood how to play the exergames and became more skilful. Becoming more skilful increases self-confidence (Feltz, 1988). This was reflected in the significant increase in effort expectancy and self-efficacy.

The significant increase in performance expectancy is most likely explained by the immediate post-exercise feelings of having had a body work-out after exergaming, suggesting that participants perceived that they would indeed derive benefit from exergaming. Most of the participants expressed a willingness to try exergaming as a new form of exercise. Once they were aware that they had used different muscle groups[19], they acknowledged themselves as having done some exercise.

Social influence also increased significantly over the course of the intervention, suggesting that there were increased social behaviour and interactions that influenced the participants preferences in relation to exergaming. This is not surprising, as partaking in a new activity such as joining a new dance class brings on more social involvement in people. People become perhaps more enthusiastic and outgoing when they have just started a new activity. Participants of the current study volunteered to participate in this exergaming study. It is possible that they may have discussed their participation with their families and friends. To some, attending sessions in the physiotherapy laboratory meant it was a day out and something to look forward to. It could also be that they had social engagements or communications before or after the exergaming sessions.

The significant increase over time in facilitation conditions in the current study showed that the participants perceived that they would be able to use the exergaming technology as they progressed throughout the intervention. A remarkable observation from the study was that gradually, some participants were able to anticipate the movements of the exergame animations (e.g. the entry and exit of the virtual objects). Some could also recall the background music and sounds.

[19]expressed in the open-ended evaluation about their exergaming experience (see Subsection 3.4.7 on page 108).

The current study also found that behavioural intention significantly increased over time, indicating the participants *intended* to use the exergaming technology for exercising, if it were readily made available. There are several possible explanations for the increase in behavioural intention in the current study. Collectively, the other technology acceptance variables have a relationship with behavioural intention (Davis, 1989; Davis et al., 1989; Venkatesh et al., 2003). Within the context of the current study, performance expectancy would foster intention to use the exergaming technology if older people perceived that exergaming was beneficial exercise *and* beneficial to do. Previous studies have also reported higher levels of social support in people who exercised frequently, than those who were sedentary (Carron et al., 1996; McAuley et al., 2000, 2003). Self-efficacy would definitely contribute to behavioural intention to use exergaming once older people felt more confident in their ability to play the exergames. The self-confidence may also contribute to a sense of wanting to continue the exergaming activity or indicate a readiness to integrate this new technology in their exercise activities. The association of facilitation condition and behavioural intention is explained by older people's perceived ability to use the exergaming technology, as already reflected in the significant increase in facilitation condition over time.

Other factors related to exergaming may also explain the significant increase in behavioural intention. One is the instrumental versatility of exergaming in offering individual adjustment and choice (Merians et al., 2002; Broeren et al., 2004). The participants exercised in the exergaming environment according to their preferred levels. This gave them control over desired levels of challenge in the exergames. For example, some participants enjoyed exergaming at low skill and low challenge levels, while some preferred low skill and high challenge levels. An example of low skill and low challenge levels would be an exergame that was played with easy physical movements restricted to one area of virtual interaction with the exergame animations. An exergame level of low skill and high challenge levels would require uncomplicated movements interacting with more cognitive challenging animations such as the snowboarding game. Stepping side-to-side required for snowboarding was a fairly easy physical movement. High challenge was in the random entry and type of animations for which the snowboarder had to either avoid or approach[20].

Studies have shown that environmental factors influence the frequency and levels of physical activity (Sallis et al., 1998; Humpel et al., 2004; Tucker and Gilliland, 2007). An example is the effect of weather on walking activity (Humpel et al., 2004). Therefore, the indoor characteristic of exergaming may appeal to some older people. First, it facilitates exercise all year round. Second, it may offer social interaction for people who enjoy exercising in a social context where they can meet friends and new people in the indoor exercise settings.

Perhaps the most influential factor in explaining the increase in older people's behavioural intention increase is the experience of flow during exergaming. The phenomenon of flow is defined by a state in which people become so absorbed in an activity that nothing else seems to matter to them. It is also described as an optimal state in which the individual enjoys and is able to meet the demands and challenges re-

[20]avoid hitting the snowman or go up the ski ramps.

quired in that activity, loses awareness of the self, yet the individual is able to maintain control and concentration, and feels an intrinsic satisfaction at the end of that activity. For an individual experiencing flow, everything seems to be happening automatically (Csikszentmihalyi, 1975).

Enjoyment is a component of flow (Csikszentmihalyi and Csikszentmihalyi, 1988; Csikszentmihalyi, 1990). Within the context of Information Systems, Davis et al. (1992) defines enjoyment as the extent to which people perceive using the computer to be enjoyable in its right, without taking into account any performance consequences that may be anticipated. In a study that investigated the relative effects of usefulness and enjoyment on use intention and computer usage in a workplace, both usefulness and enjoyment accounted for 62% of the variance in usage intentions (Davis et al., 1992). People are more likely to accept technology if using it creates an enjoyable experience which, in turn, represent affective and intrinsic benefits (Davis et al., 1992).

The current study found significant increases over time in the flow variables, as similarly observed in the technology acceptance variables, suggesting that older people had positive exergaming experiences. This evidence is speculative that flow experienced by the participants contributed to their further *intent* in wanting to use exergaming. Other studies have reported the high association of flow with behavioural intention. Sweetser and Wyeth (2005) reported that enjoyment was the single most important goal for online game players. Therefore, people will not play a game if they do not enjoy it. Lee (2009) found that behavioural intention to play online games was most influenced by flow experience.

Were the exergaming sessions of practical benefit?

The current study applied magnitude-based-inferences recommended by Batterham and Hopkins (2005) to examine any therapeutic effects of exergaming (shown at Table 4.3 on page 58). According to Batterham and Hopkins (2005), the ambiguity of the true value of the statistic can be shown in confidence limits, which in turn define the regions of beneficial (substantially positive), trivial (negligible), and harmful (substantially negative) values. Clinical significance is interpreted by confidence limits in relation with the smallest or most minimal clinically beneficial or harmful effects.

All technology acceptance variables showed a substantially positive effect. This indicated an overall improvement in older people's exergaming skills over time. This also suggested that the more exergaming sessions they had, the more health benefit was perceived from exergaming. The substantially positive effect found in social influence could be reflective of the supportive role played by social influence (Brown, Nesse, Vinokur and Smith, 2003) in encouraging older people's exercise behaviour[21].

Although a significant increase in challenge-skill-balance was found over time, results showed that the effect was trivial. The same was found for perceived mental effort. A possible explanation is that in subsequent sessions the participants were already familiar with the exergaming applications and therefore knew what to expect in every session. Another reason could be that the IREX^{TM} system was designed for rehabilita-

[21] which is behaviour to use exergaming.

tive purposes and that the sample population in this study was relatively fit and active older adults. The possibility that some of the participants found the exercises too easy to do therefore cannot be ruled out.

A trivial effect was found for paradox of control, action-awareness-merging and transformation of time. A plausible explanation is that interaction with the simulated virtual environment was designed for the participants to respond to the exergaming system. For example, when participants missed the target during the first attempt, the game continued regardless of whether they were able to quickly adjust their position or make a compensatory move to reach the next target. Simply stated, the game just moved on unless it was stopped or finished. Participants were already aware of the time sets allocated for each exercise application. However, another possibility is that the game applications were not long enough for the participants to acquire a sense of time loss.

Unambiguous feedback showed a 50-50 beneficial-trivial effect. This could be due to differences in the perceptions and expectations of the participants on their exercise experience. Some participants had expressed themselves as feeling more confident of their movements, but instead received lower scores graded by the exergaming system. In some cases, the game applications were close to ending before participants had figured out how to coordinate their movements or adjust to the spatial perspective of the projected image of themselves on the television screen. Interestingly, a highly beneficial, but not statistically significant, effect was found in perceived physical exertion. This showed that despite familiarity with the exergaming applications, most were willing to persist or put in physical effort during the exercise sessions.

3.5.2 How do older people feel about exercising in a virtual environment?

A large volume of published studies has described older people's perceptions of exercise, motivations, and barriers to physical activity (Grossman and Stewart, 2003; Bunn et al., 2008; Wandel and Roos, 2006; Kruger et al., 2007; Lee et al., 2007; Grant, 2008; Eyler et al., 1999). At present, studies investigating the effects of exergaming in older people are also increasing (Plow et al., 2011). Nevertheless, those describing older people's perceptions about performing the exergaming activity are very few.

Only two studies report qualitative findings of older people's exergaming experiences. Wollersheim et al. (2010) conducted focus group meetings with 11 older women who exercised using the Wii at a six-week duration. Their findings showed that an overall improved sense of physical, social and psychological well-being amongst the participants. Their exergaming experience reinforced social interaction within the group and fostered shared experiences with younger aged family members. Marston (2010) interviewed older people in relation to their preferred digital games, what motivates them to play those games and whether exergaming increased their social network. Exergaming studies that exist in the literature agree that older people *will* show interest in exergaming *if* they can achieve health and social benefits from it.

The current study used an open-ended evaluation to gain insights into older people's perceptions of their exergaming experience. After every exergaming session, they were asked what they thought of the session. Most participants reported having enjoyed “exercising with a computer” and were willing to try the exergaming applications. No motion sickness was reported throughout the intervention. Some participants felt that they were able to make the movements required to interact with the virtual objects within the virtual environment. Some participants also experimented with different movements within the exergames to see how they would score. The participant who did not feel that he would use exergaming exercise in future acceded that the exercise experience had indeed been fun and beneficial. This was the same for participants who complained that they could not keep up with the exergaming system during certain sessions.

Some participants also commented on the inaccuracy of the exergaming system in tracking their physical movements. This showed that they were alert and sensitive to changes in the virtual environment as visualised on the TV screen, contrary to stereotypes that view older people as slow and incompetent (Cuddy et al., 2005). This implies that the standard of exergaming applications should be improved to match higher skill levels. These findings suggest that developers of exergaming applications should not only improve the design of exergaming applications to cater for specific characteristics and needs of the users (Billis et al., 2011) but also to ameliorate any limitations in the immersive motion capture technology.

These qualitative findings demonstrated that firstly, older people reacted positively towards the exergaming technology. Secondly, they were willing to use computers for exercising. Third, they were able to enjoy exergaming and were willing to persist despite any difficulties encountered. Fourth, they felt that exergaming was beneficial to people from all walks of life. The exergaming benefits were described as (1) helpful to those who needed physical rehabilitation, (2) enhancing psychological states, (3) a form of social activity for friends to get-together and (4) an excellent form of indoor exercise.

In summary, most participants in the study were receptive to exercising in the exergaming environment. There was no indication that they could not perform the exercise and of any adverse effects in using exergaming.

3.5.3 Does older people's previous behaviour influence their future intention to use the exergaming technology?

The current thesis investigated the influence of variables from the UTAUT on their expressed intention to use the technology again, and found that performance expectancy (PE) was the major influence. It also investigated the influence of previous use on expressed intention to use it again and found this to be a strong predictor.

The finding that PE was the strongest predictor of BI indicated that participants' perceptions of the benefits they would derive from exercising in the virtual environment influenced their intention to use the exergaming system in future, if readily made available. This is in agreement with the UTAUT model (Venkatesh et al., 2003). It is consistent with findings with other technology that the main factor that motivates technology use by older people is their perception of the actual benefit that they will obtain (Goodman et al., 2003*b*; Melenhorst et al., 2006).

The generally non-significant results for the other variables did not conform with the model, which predicted that they would also influence BI (Venkatesh et al., 2003). With other technology, outwith the context of exercise, effort expectancy has been shown to be particularly influential in older people especially in the early stages of technology use. Subsequently, this influence becomes less important with prolonged exposure to the technology (Davis et al., 1989; Morris and Venkatesh, 2000). However, results showed that it only appeared as significant on two occasions at T4 and T6.

In this study EE may have been less important than expected because, within the constraints of the study, the use of the technology and the difficulty of the physical movements were supervised and relatively controlled. Social influence is recognised as being diminished when the technology use is primarily voluntary (Davis et al., 1989; Davis and Venkatesh, 2004), which was the case in this study. The specific technology use was mandatory because participants followed a set protocol. However, their decision to take part was entirely voluntary and, in line with the agreed ethics principles, they were free to withdraw from the study at any time with no adverse effects. (It is difficult to envisage any other circumstances in which exergaming would be mandatory.) Furthermore, the fact that technology use was solitary rather than with a group of peers may have reduced the influence of SI.

No clear evidence of gender influencing BI was found, but it is difficult to make any firm suggestions because of the very small number of men in the sample. Similarly, age is considered by the UTAUT to be important but that is based on studies across the adult range (Morris and Venkatesh, 2000). In contrast, the participants in our study were from a more restricted age range, although that age range is by no means automatically homogeneous. Furthermore, the voluntary, as opposed to mandatory, use of the technology may have affected the expected influence of age.

The idea that previous behaviour can be used to predict future behaviour was originally described in the Theory of Planned Behaviour (Ajzen, 1991). In the field of information systems, researchers have used previous behaviour to test models designed to predict future behaviour under the assumption of other stable determinants (Limayem et al., 2000; Davis and Venkatesh, 2004; Cheung and Limayem, 2005). Results from the second modified UTAUT model showed that BI at T0, before the participants had actually used the technology, was significantly predictive of BI at the next time point T1. Consequently, previous BI significantly predicted current BI at all time points, in agreement with information systems research associated with previous usage (Bolton and Lemon, 1999; Davis and Venkatesh, 2004; Cheung and Limayem, 2005). Interestingly, at T3, while previous BI remained a significant determinant of the subsequent BI, other acceptance variables emerged as non-significant, consistent with the findings of Davis and Venkatesh (2004).

In their research on early user acceptance testing on new information systems, Davis and Venkatesh (2004) found that constructs of intention and perceived usefulness measured before actually starting work on a particular IS application were closely related to hands-on usefulness measures taken after prolonged time periods, and could significantly predict both the intention to use and usage behaviour up to six months after implementation of that application. In other words, how people see or regard a specific application influences their decision on wanting to use that application in future. When introduced to a specific technology, people form perceptions about whether it will be of any use or benefit to them. The most valuable information was that the perceptions formed even before trying out the application (before hands-on experience) were similar to those formed after usage, and could significantly predict the future intention to use the technology (Davis and Venkatesh, 2004).

3.6 Limitations and Conclusion

This study presents evidence of older people's acceptance and intention to use exergaming. It has not shown that older people reject exergaming technology. Overall, participants reported their exergaming experience to be positive and engaging. Not only did the participants welcome the technology but also enjoyed the exercise experience. There is a possibility that older people are able to learn to use it given suitable training methods and attention to readied access for them. This may encourage older people's long-term maintenance of physical activity and aid concordance with future therapeutic exercise programmes.

While most, but not all outcome measures improved or changed over time, no evidence of decrease in the quality of the experience was found. Therefore, exergaming is likely to be well received by older people. The significant increase of flow measures over time showed that flow experience was indeed achievable through exergaming and may play a role in the intrinsic motivation of older people to continue exercise. An understanding of the elements that facilitate flow state in exergaming may have important implications for future physical activity promotion strategies for older people. these results support an expectation that older people from this population, after using exergaming technology for exercise, are very likely to use it in the future.

The findings of the study should be considered in the context of the study's limitations. The sample was small in size and comprised healthy and physically active older people. This may introduce a possible bias into the study. However, the likely acceptance of exergaming is an important finding. Having established acceptability of exergaming in healthy older people, this leads to the question of whether exergaming acceptance will be different in older people with chronic pain. Acceptability of the technology in this population would offer opportunities to engage them with exergaming as a therapeutic activity.

Chapter 4

Second study: Exergaming acceptance and experience in older people with chronic musculoskeletal pain

4.1 Introduction

The previous study showed that exergaming was favourable to healthy older people of whom, after using the exergaming technology for exercise, expressed intention to use it in future, if readily made available. Performance expectancy was a major predictor of older people's intention to use exergaming technology. The investigation was then extended to older people with chronic musculoskeletal pain. Chronic pain, health status and function in this sample was also described. The effects of exergaming in their balance was further investigated in comparison to those of a standardised exercise protocol.

The organisation of this chapter is as follows: Section 4.2 presents the background of the study. Section 4.3 outlines the research methodology, outcome measures and data analyses. The results are described in Section 4.4. Section 4.5 then discusses the findings from this population of older people with chronic pain, study implications, and concludes the study.

4.2 Background

Prevalence of self-reported musculoskeletal pain in the elderly is estimated at 36% to 70% (Crook et al., 1984; Brattberg et al., 1996). Persistent pain seems to occur twice higher in older people aged 60 years and above rather than in younger people (Brattberg et al., 1996; Buskila et al., 2000; Helme and Gibson, 2001). Chronic musculoskeletal pain involves sensory, emotional and cognitive components (Burris, 2004; Frondini et al., 2007). Older people suffering from chronic pain may also have impaired balance (Boucher et al., 2008) and have a particularly high risk of falling (Leveille et al., 2002; Sturnieks et al., 2008). Chronic musculoskeletal pain has also been associated with depression, problems with sleep (Blagestad et al., 2012), impaired mobility (Campbell et al., 1981; Leveille et al., 2002), increased health care costs (Ferrell, 1996; Maniadakis and Gray, 2000) and reduced quality of life (Breivik et al., 2006; Currie and Wang, 2004).

Exercise is a frequently prescribed treatment for older people suffering from chronic pain (Rainville et al., 2004). However, despite the known benefits of exercise, older people are still not doing enough (Grossman and Stewart, 2003; Crombie et al., 2004). Older people commonly cite pain and illness as reasons for not exercising (Cooper et al., 2001; Grossman and Stewart, 2003). Some are convinced that they get enough exercise from doing housework (Grossman and Stewart, 2003). Some even believe that exercise would not improve their condition (Rimmer et al., 2008). Other reasons putting older people off exercise are personal and environmental-associated problems (Rimmer et al., 2008), such as travelling to the fitness centre or simply a lack of interest in exercise (Crombie et al., 2004).

Recently, exergaming has become a popular physical activity with the advantage of low-intensity exercise-and-play (Bogost, 2005) within an enclosed environment (i.e. performed indoors) (Görgü et al., 2012). Previous studies have evidenced health benefits in exergaming among older people, such as significant improvement in depressive symptoms, mental-health-related quality of life and cognitive functioning (Rosenberg et al., 22010), motor function (Saposnik et al., 2010) and balance (Clark and Kraemer, 2009; Agmon et al., 2011). There is also evidence of greater ease of physical movement and improved psychosocial well-being in older people after exergaming (Wollersheim et al., 2010). Enjoyment is one of the psychosocial benefits frequently reported in older people who have participated in exergaming (Wollersheim et al., 2010; Williams, Soiza, Jenkinson and Stewart, 2010). Taking this evidence collectively, it seems that older people may have much to gain from exergaming if the technology is acceptable to them. In fact, exergaming may also appeal to older people and arouse their interest to simultaneously try something new and become more physically active. If this is so, the question of whether exergaming has any effect on older people's balance is particularly important, especially if older people with chronic musculoskeletal conditions have impaired postural control (Mientjes and Frank, 1999; Kuukkanen, 2000; Hassan et al., 2001; Boucher et al., 2008).

Therefore, this study aimed to assess firstly, whether exergaming technology was acceptable to older people with chronic musculoskeletal pain, and whether exergaming had any effect in older people's self-reported health status, physiological response and balance.

4.3 Method

4.3.1 Study Design

A randomised control trial was conducted. The independent variable was type of exercise (standard or exergaming). The dependent variables were behavioural intention, performance expectancy, effort expectancy, social influence, facilitating conditions, self-efficacy, flow experience, pain, disability, balance, physical and mental effort and heart rate. Demographic variables were age and gender.

4.3.2 Location and Governance

Ethics approval was sought from and granted by the School of Health and Social Care Research Governance and Ethics Committee at Teesside University on 20th September 2010 (see Appendix G.1 on page 334). The study was conducted in the Physiotherapy Research Laboratory, Constantine Building, Teesside University.

4.3.3 Recruitment

Participants were recruited by non-direct contacts from nine local community groups in the Middlesbrough area. Inclusion criteria were the following: Aged 65 years and above, able to walk unassisted (i.e. does not use or require any walking aids) for at least 0.5 of a mile (verified by self report), having musculoskeletal pain in two or more joints, of more than 12 weeks duration (verified by self-report), and able to read and write English. Because there were significantly higher scores in behavioural intention among participants aged 65 and older than among those who were younger in the previous study investigating exergaming acceptance in healthy older people as determined by *t*-tests, a minimum age limit of 65 years selected for the current study. Exclusion criteria[1] were the following: Self-diagnosis of, or suspicion of, any systemic conditions that may cause pain in two or more joints, of more than 12 weeks duration such as cancer, rheumatic, neurological diseases or conditions, self-report of current, or history of any condition or injury which would contraindicate participation in the exercises under study, inability, or any doubt of ability, to give informed consent, and inability to comprehend and write English.

Centre managers or group coordinators were contacted by telephone to ask if they would pass on recruitment pamphlets (see Appendix G.2 on page 335) to any members of their group who were eligible and interested in participating. Participant information was then sent to these gatekeepers to request permission to invite eligible people to consider participation (see Appendix G.4 on page 338). The relevant managers or group coordinators were also asked to make available the study recruitment pamphlet in any suitable public spaces where potential participants may see them.

In addition permission was requested for the researcher to give a ten minute presentation on the study to members of these organisations during or after a scheduled meet-

[1] Previous exergaming experience was not an exclusion criteria.

ing/gathering where the centre manager or group coordinator considered that eligible people may be present. The presentation was given by the researcher and included factual information on the study and an invitation for anyone interested to ask questions and consider participation. Copies of the participant information sheets (see Appendix G.4) and Reply Slips (see Appendix G.3 on page 337) were left at the premises for any interested potential participants to take away. Reply slips were returned directly to the researcher or via a relevant manager or group coordinator to be passed on to the researcher.

On receipt of a completed Reply Slip the potential participant was contacted by the researcher using their preferred mode of contact. A first appointment was made for those who were interested to attend the physiotherapy lab at Constantine Building, Teesside University. At that appointment potential participants were given another copy of the PIS, and asked if they had any further questions, which were answered by the researcher. They were then invited to complete the Consent Form (see Appendix G.5 on page 352). Participants were encouraged to ask the researcher any questions regarding any aspect of the research. Letters to their general practitioners were sent to inform their participation, if they wished.

4.3.4 Participants

Fifty-four participants (42 women, 12 men) were recruited (age range 65–86 years, mean 71 years, SD 5; height mean 161.24 cm SD 7.71; weight mean 72.83 kg SD 18.12). Figure 4.1 shows the CONSORT flow diagram of their recruitment. Participants' demographics are shown at Table 4.1. All participants were Caucasian with self-reported chronic pain, and most were retired. Chronic pain was reported to be prevalent in the following body locations: hip, hands/wrists and back (see Appendix H on pages 355–357).

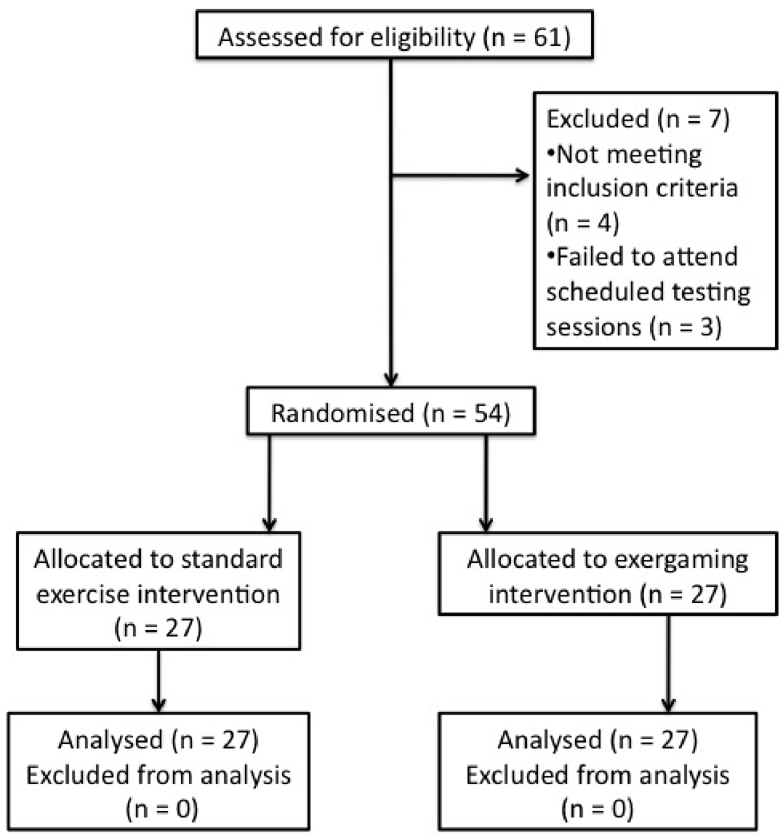


Figure 4.1: The recruitment of older people with chronic pain and exclusions

4.3.5 Equipment

An exergaming intervention that consists of a computer installed with virtual-reality (VR) software, a television monitor, a digital camera and a large screen (previously described in Chapter 3 on page 76).

Table 4.1: Participant demographics

	Control (n = 27)	Experimental (n = 27)
Male	7	5
Female	20	22
Independent living	26	26
Assisted living	1	1
Retired	26	26
Working part-time	1	1
	Mean (SD)	Mean (SD)
Age (years)	69.78 (4.48)	71.78 (6.10)
Height (cm)	162.16 (6.74)	160.33 (8.60)
Weight (baseline) (kg)	69.27 (13.28)	76.39 (21.61)
Weight (post) (kg)	68.72 (13.03)	77.31 (22.20)

Polar Heart Rate monitor

Worn on the wrist, the monitor receives signals from the elastic sensor belt comfortably strapped across the chest and displayed heart rates on its screen (see Figure 4.2). It offers an objective measure of physical exertion throughout exercise activity by monitoring heart rate responses and is vastly used in the field of sports and rehabilitation to gain levels of performance. Heart rate[2] is easily measured by wearing a monitor around the chest at skin level and wearing a watch which picks up the heart rate output.

Kistler force platform

The Kistler force platform (Model 9286AA, Kistler, Alton, UK) - W 40 x L 60 x H 3.5 cm - with a sampling rate of 1000 Hz, was used to collect postural sway data (see Figure

[2]In study 1, the investigation was focussed on healthy older people's acceptance and subjective experience of exergaming. Therefore, heart rate was not measured as an outcome variable.

Figure 4.2: Polar heart rate monitor, watch and strap

4.3). The data were the range and standard deviation of the CoP excursions in the anterior-posterior and medio-lateral directions (AP range, AP SD, ML range, ML SD respectively, all mm) and the CoP velocity (mm.sec^{-1}) (Raymakers et al., 2005) during quiet bipedal standing.

Figure 4.3: The Kistler force platform

The platform comprises four triaxial piezoelectric force transducers embedded within each of its corners. When people stand upright, the feet are constantly in contact with the ground. Due to gravity, there are interactions between the feet and the supporting ground. A force vector, known as the ground reaction force, combines both gravity's effect on the body and the effects of the body's movement and acceleration (change of velocity) in three planes of reference. The location of the three ground reaction force vectors on the ground is called the centre of pressure (CoP). Hence, force platforms are used to quantify the location of the CoP. CoP velocity was calculated using previous methods (Raymakers et al., 2005) after low-pass filtering of the raw data at 10Hz. Force platforms are also used for measuring dynamic postural stability.

However, the current thesis aimed to generate a clinically relevant summary of static balance in association with an exergaming intervention, rather, as a secondary outcome measure. Sensory manipulation was achieved through two conditions – eyes closed and eyes open.

4.3.6 Outcome measures: Quantitative

Technology acceptance measures

Technology acceptance variables (defined earlier in Chapter 2 on page 18) were measured using modified Unified Theory of Acceptance and Use Technology (UTAUT) questionnaires (Venkatesh et al., 2003) (see Appendix B on pages 259 and 261).

Flow variables

Flow variables comprise the following: autotelic experience, clear goals, challenge-skill-balance, concentration at task, paradox of control, unambiguous feedback, action-awareness-merging, transformation of time and loss of self-consciousness, respectively. They were defined earlier in Chapter 2 on page 22. The Flow State Scale (Jackson and Marsh, 1996) was used to measure these variables (see Appendix B on page 265).

Pain

Pain occurrence was recorded using a self-reported pain recording form (see Appendix G.7 on page 354). Participants were asked to indicate their average pain in each location (e.g. hands/wrists, foot, back, chest) on a scale of 0-10, with 10 being the worst possible pain. Pain intensity experienced within 30 days and experienced at present was rated at the first and last sessions of testing at the laboratory. Three major aspects of pain (somatosensory, emotional and well-being) were measured using the Multi Affect and Pain Survey (MAPS) questionnaire (Clark et al., 2002) (see Appendix B.5 at page 272).

The MAPS questionnaire developed by Clark et al. (2002) was used to measure pain in older people with chronic musculoskeletal pain. It consists of three supercluster measuring pain sensations (i.e. somasosensory) and both negative (i.e. emotional) and positive emotions (well-being) related to having pain. There are a total of 101 descriptors of pain and emotion structured into a dendrogram determined by cluster analysis from an initial set of 270 descriptors (see Table 4.2 on page 153). The descriptors are grouped into 3 subclusters. The somasosensory pain supercluster contains 17 clusters with 57 descriptors of painful sensory qualities; the emotional pain supercluster has 8 clusters with 26 descriptors of negative emotional qualities; and the well-being supercluster has 18 descriptors of positive affect and health grouped into five clusters. MAPS has been validated in various pain studies (Yang et al., 2000; Clark et al., 2003; Knotkova et al., 2004, 2006).

To further understand pain occurrence in this population of older people, self-reported pain was classified into four groups following Leveille et al. (2002). In their study investigating musculoskeletal pain as a risk factor for falls in older women, Leveille et al. (2002) categorised pain into four groups, where the first group represented moderate to severe widespread pain; the second represented moderate to severe lower extremity pain that did not meet the criteria for widespread pain; the third represented the reference category of no pain or mild pain in one site; and the fourth represented pain that did not fit into the other three groups. Older women with chronic widespread pain were at the highest risk of falls compared to women with no pain or mild pain at one musculoskeletal site. In fact, the risk of falling was evident for women who suffered from musculoskeletal pain that was not widespread or occurred in the lower extremity (see Appendix B.9 on page 280). Within the current thesis, the classification of pain according to Leveille et al. (2002) would at least show pain prevalence in the sample population from another perspective.

Health status, function and disability

Participants' health status, function and disability was assessed using the WHODAS-II (WHO, 2000*b*) (see Appendix B.4 on page 267). This provided a means of understanding the health status and levels of functioning and disability in this sample of older people. Scoring the WHODAS-II was based upon averaging responses and then transforming scores into a standard scale. The WHODAS-II scores were assigned to each of the items: "none" (1), "mild" (2) "moderate" (3), "severe" (4) and "extreme" (5). Scoring was then based upon averaging responses and then transforming scores into a standard scale.

Table 4.2: Superclusters, clusters and descriptors of MAPS (Clark et al., 2002)

Somatosensory pain supercluster		
1.	Cutaneous	itchy, irritating, crawling, tickling, tingling
2.	Temporal	flickering, intermittent
3.	Faint pain	dull, mild
4.	Muscle/joint pain	stiff, tight, sore, aching
5.	Autonomic distress	disgusting, nauseating
6.	Sensory distress	disturbing, bothersome, distressing, distracting
7.	Thermal	burning, hot
8.	Pain extent	spreading, persistent, worsening, pervasive
9.	Intense pain qualities	vicious, excruciating, nasty, overwhelming
10.	Intermittent pressure	throbbing, pounding
11.	Brightness	stinging, smarting
12.	Incisive pressure	sharp, shooting, biting, deep, tearing, stabbing, gnawing
13.	Traction/Abrasion	tugging, crushing
14.	Respiratory distress	choking, suffocating
15.	Cold	cold, cool
16.	Numb	numb, numbing
17.	Pain restriction	localized, restricted
Emotional pain supercluster		
18.	Physical illness	ailing, suffering
19.	Depressed mood	lousy, rejected, depressed, discouraged, miserable, lonely
20.	Self-blame	guilty, negligent
21.	Anger	angry, outraged, upset, annoyed)
22.	Anxiety	stressed, anxious
23.	Fear	alarming, startling, frantic, terrified
24.	Emotional avoidance	apathetic, stoical
25.	Physical avoidance	exhausting, sleepy, tiring, sluggish
Well-being supercluster		
26.	Treatable illness	curable, mangeable
27.	Mentally engaged	interested, involved
28.	Physically engaged	active, vigorous
29.	Affiliative feelings	loved, forgiving, affectionate, sympathetic
30.	Positive affect	hopeful, happy, relaxed, encouraged, cheerful, satisfied, calm

The modified WHODAS is the WHODAS-II, a disability instrument designed based on the International Classification of Functioning, Disability and Health framework (WHO, 2000*a*), assessing six domains of functioning in daily life. The six domains are Understanding and Communicating, Getting Around (i.e. mobility), Self-care (e.g. washing, bathing, getting dressed), Getting Along With Others, Life Activities and Participation in Society (i.e. taking part in activities in the community). Available in 11 versions and 16 languages, the WHODAS-II applies more broadly to the impact of disorders irrespective of medical diagnosis on everyday functioning, and treats all physical and mental disorders (WHO, 1988) equally when determining the level of function (WHO, 2000*b*). The high reliability and validity of the WHODAS-II have been widely reported (McKibbin et al., 2004; Chwastiak and Korff, 2003; Norton et al., 2004; Garin et al., 2010; Meesters et al., 2010; Schlote et al., 2009).

Balance measures

Balance outcomes were the centre of pressure velocity (CoP velocity, mm per second), and the range and standard deviation of the excursions in the anterior-posterior and medio-lateral directions (AP range, AP SD, ML range, ML SD respectively in millimetres) during quiet bipedal standing. The CoP velocity is the location of three ground reaction force vectors which define the position of average pressure point from the feet when people are standing upright (Winter, 1984). The quantification of the CoP velocity by using force platforms has been extensively applied in posture and gait research (Winter, 1984; Stacoff et al., 2005; Raymakers et al., 2005). In the current study, the Kistler platform was used to collect the balance measures (see Section 4.3.5 on page 148).

CoP velocity provides important information about the rate at which the CoP moves within and about the base of support when people are standing upright quietly (Palmieri et al., 2002). It has been measured in previous studies measuring balance and for detecting changes in balance, as influenced by age and availability of visual information (Prieto et al., 1996; Raymakers et al., 2005). When a person is standing quietly, how much movement that is done by the CoP can be measured by using the AP and ML distance between the length of sway in each direction. Therefore, sway range is able to measure how much the CoP moves (Hertel and Olmsted-Kramer, 2007). The standard deviation (SD) is a standard measure in balance performance where it can reflect a person's postural behaviour when they are standing quietly (Vuillerme et al., 2008). The SD is also the square root of the variance where it measures how far the mean CoP has moved during standing balance. Hence, the SD is sometimes referred to as the root mean square amplitude (Palmieri et al., 2002).

Perceived physical and mental effort, and heart rate

Perceived levels of physical exertion and expended mental effort during the intervention were measured using the Borg RPE and SMEQ (see Appendix C on pages 282-283). Previous studies have used the Borg RPE to assess levels of perceived physical exertion (Eston and Evans, 2009; Eston, 2009; Chen et al., 2002; O'Neill et al., 1992; Karavatas and Tavakol, 2005). The SMEQ has been applied in previous studies (Carsten, 1999; Sauro and Dumas, 2009; Hassenzahl and Sandweg, 2004; van der Schatte Olivier et al., 2009). Heart rate was recorded using the Polar heart rate monitor (see Figure 4.2). This device has been clinically validated in previous studies (Goodie et al., 2000; Kingsley et al., 2005; Gamelin et al., 2006; Segerståhl and Oinas-Kukkonen, 2011).

4.3.7 Randomisation

Randomisation was performed by blind-card allocation (picking a sealed opaque envelope) to either the exergaming, or standard exercise group.

4.3.8 Exercise intervention

The exercise intervention consisted of six 40-minute exercise sessions within a six-week period. The duration of six weeks for the exercise sessions was selected for the current study based on evidence of indications of minimal clinical effects from six-week exercise interventions from previous studies (Shamliyan et al., 2012). The instructions for the exercise intervention are shown at Table 4.3 on page 160). Each exergaming application that comprised two minutes duration was repeated three times within a session. Each set of standardised exercises that comprised two minutes duration was repeated three times within a session. All participants were also given rest periods of 10 to 30 seconds, or longer, if required, between exergaming applications, or standardised exercises sets.

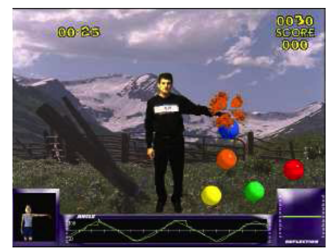
Table 4.3: Instructions for the exercise intervention in the current study

		Exercise instructions	
	Purpose	Control[3]	Experimental
1	To encourage physical movement of the upper extremities and balance	Stand up straight with knees slightly bent and your feet shoulder width apart. Clasp both hands in front of your abdomen and slowly raise both arms to the front until eye level, and lower both arms. Repeat 3 times. Following this, stand comfortably with both arms by your sides. Raise the right arm away from your body until shoulder level and then lower it down again to your side. Repeat with the left arm. Following this, move two steps to the right and repeat the movement of the arms; repeat with movement to the left.	Volleyball: Land the ball in your opponent's court or outside your court. Either move your body, shoulder or touch the volleyball by hand. Smoother movements allow better contact with the ball.

[3] Adapted from ACSM's Guidelines for Exercise Testing and Prescription (2009) and Brecher (1997)

2	To encourage full body movement with bending and stretching	Stand up straight with knees slightly bent and your feet at a comfortable width apart. Stretch out both arms so that they form a T with your body and slowly bend your knees to a comfortable position. Keep your back straight, while in this position, transfer your weight to the right leg and reach out to the right side with your upper torso and right arm as much as you can. Hold for 2 seconds and gently move your position back as you were before you reached to the right. Repeat with the left side.	Sharkbait: You will see yourself virtually deep-sea diving with sea creatures. Catch as many stars as you can. Lean side-by-side, crouch down or raising your arms. To move sideways quickly, step to the side. If you meet a shark, it will virtually swallow you and expel you out of its mouth. Contact with an electric eel virtually temporarily disables your movement.
3	To encourage trunk mobility, movement of the upper torso and balance	Stand up straight with knees slightly bent and your feet shoulder width apart. Gently hold both hands in front of your torso with both elbows bent. Look straight ahead while maintaining a relaxed stance, and gently turn your body to the right and back to original position, then to the left and back to original position. Repeat this time with your arms extended.	Formula racing: You will see yourself virtually driving in a Grand Prix. The course of the track is also visible to you. Drive through the racecourse as best as you can. Steer by stepping to the right or left, by moving your body to the side, or by moving one arm at a time. If you feel that you have not moved on the track, take one small step to the side to move your car.

4	To encourage full body movement, working on pelvic tilt and hamstrings	Stand up straight with your feet shoulder width apart. Place your hands in front of your body as if to hold an imaginary ball and look straight ahead. Move your pelvis to the front (towards your hands) and hold for 2 to 3 seconds, and to the back. Repeat as many times as you can. Next stand upright and take a comfortable step forward with your right foot (almost into a lunge position). Rest your hands on your hips and gently tilt your body to the right and back to where you started. Repeat this by standing upright again, this time with a step forward with your left foot, resting your hands on your hips and gently tilting your body to the left, and back to where you started. Try to keep your upper body upright and your back as straight as possible.	Snowboard: You will see a red silhouette of yourself standing on a snowboard, coming down a narrow slope, and a virtual image of yourself when you cross the finish line. Begin by stepping sideways until you are centred over the snowboard. Make as many jumps as possible and avoid hitting other objects. Lean to either side, or move your arm to one side.

5	To encourage shoulder rotation, fine motor exercise and movement of the upper extremities	Stand up straight with your feet shoulder width apart. Place both arms at your sides. Beginning with the right arm: slowly move your right arm upwards until shoulder level and gently open and close your right hand (this involves movement of the thumb, fingers and palm). Repeat with your left arm. As you progress through the sessions, use both arms at different positions (e.g. to the top of your head, stretching to the top left or right).	Birds and Balls: You will virtually be in a pastoral background with colourful balls coming at you. Touch the balls with any part of your body e.g. once you have exercised with your right shoulder or arm, you may repeat it with the left. The balls will not pop if they are approached with a gentle touch. 

Note. Images for the other exergame applications are shown earlier at Table 3.1 on page 84.

4.3.9 Procedure

On arrival for data collection at the Physiotherapy Research Laboratory at Teesside University, participants were asked if they had further questions about the study. These questions, if any, were answered by the researcher. The Consent Form (see Appendix G.5 on page 352) was then signed, after which the participants were randomised into their respective groups. The time of data collection of which was suitable and convenient to the participants was arranged with them. All participants were asked to report to the laboratory twice a week for 40 minutes each session over a six-week period. Each session comprised either five interactive IREX^{TM} games or five physical exercises, where each game or physical exercise were of two minutes' duration, and adequate periods of rest between 10 to 30 seconds, or longer if desired, were given to participants. Physical exercise for the control group matched the movements of the body and muscle groups of those required in the experimental group.

Participants' demographic details were recorded: weight (kg); height (cm); age (years); gender (M/F) and the description of pain occurrence, location and intensity. Participants were invited to fill in the WHODAS-II (WHO, 2000*b*) and MAPS (Clark et al., 2002) questionnaires at this time (i.e. considered to be baseline, T0). Filling in the WHODAS-II and MAPS questionnaires was repeated at the end of the intervention (at the twelfth point of data collection, T12).

Similar to the first study, participants were asked to complete the modified Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) questionnaire before taking part in either exergaming or performing standardised exercises. Following this, participants' balance measurements were taken where they stood tested barefoot for bipedal quiet standing on a Kistler force plate with eyes open and eyes closed (see Figure 4.4 on page 163). Participants completed all three trials of one condition before testing took place under another condition. The tests were performed three times. Each test repetition lasted for 30s duration. Each participant performed three bipedal tests three times to add to reliability of testing. Participants were asked to look directly in front of them at the wall where a visual target was positioned 3 meters from the centre of the force plate at eye level. Once they stood on the force plate, the balance measures were recorded. Following each 30-second trial during the bipedal stance, participants stepped off the force plate and had a 15-second rest before starting the second trial.

After that, participants either took part in the first exergaming or standardised exercise session. Heart rate was recorded three times during each exercise session (i.e. at 15 and 30 minutes, and at the end of the exercise activity). Participants were also asked to rate how much physical exertion and mental effort they had expended during the game applications, where the BORG (Borg, 1970*a*) and SMEQ (Zijlstra, 1993) scales were used in assessing their perceived effort. This occurred three times during each standardised exercise or exergaming session. Upon completion of every session, participants were invited to answer the modified UTAUT questionnaire and Flow State Scale (Jackson and Marsh, 1996). All questionnaires were completed by each participant independently from the researcher. However, when someone had difficulty reading the researcher sat with them and read the questions aloud.

On the last session of the six-week intervention, balance measures were recorded again after performing the last exercise session. The WHODAS-II, MAPS questionnaire and pain recording forms were completed again. Hence, outcome measures at baseline and upon completion of the study comprised the following: Technology acceptance variables, balance measures, self-reported health and function measures (i.e. the WHODAS-II variables), MAPS variables and self-reported pain. Outcome measures at every session comprised the following: technology acceptance variables, variables of flow, recorded heart rate, and perceived physical exertion and subjective expended mental effort.

Figure 4.4: Quiet standing

4.3.10 Data analysis

Descriptive statistics were calculated for the sub-scales of the modified UTAUT questionnaires and Flow State Scale scored by participants. This was followed by calculating Cronbach's alpha to evaluate internal reliability for the sub-scales. Analysis of covariance (ANCOVA) was used to assess between-group final scores for each sub-scale of questionnaires used with baseline scores as covariate. Mixed analysis of variance (ANOVA) was used to determine any within-subject changes over time. Related *t*-tests confirmed changes at the start and end of the intervention in each group. Between-subject differences (i.e. the effect of intervention) was not interpreted from the mixed ANOVA. Differences in flow levels in each group at the start and end of the intervention were determined by Wilcoxon's signed-rank test.

Moderated multiple regression was used to analyse the data for technology acceptance measures. The first model was based on a modified version of the Unified Theory of Acceptance and Use Technology (UTAUT) (Venkatesh et al., 2003) (described earlier in Chapter 3 on page 64). The dependent variable was BI. Predictors entered into the regression were performance expectancy (PE), effort expectancy (EE), social influence (SI), age (AGE), gender (GDR) and intervention (INT). The model was regressed using the enter method for four time points (i.e. T1, T4, T8 and T12). Hierarchical regression was also applied when products between the predictors were included in the model. In the first block, direct effects (PE, EE, SI, AGE, GDR and INT) were entered. Next, interaction terms (PE x GDR, EE x GDR, SI x GDR, PE x AGE, EE x AGE, SI X AGE, PE x INT, EE x INT, SI x INT and AGE x GDR) were entered in the second block.

The second model simulated Davis and Venkatesh (2004) (described earlier in Chapter 3 on page 68). The independent variables were entered into the regression equation in three successive steps. In the first step, (1) BI from the previous session; (2) the main effects (PE, EE, SI, AGE, GDR and INT); and (3) the two-way interaction terms (BI x GDR, BI x AGE and BI x INT), were entered, respectively (previously shown at

Figure 3.3 on page 72).

Chronic pain intensity before and after the intervention were analysed using student's *t* test. Statistical analysis similar to those of the modified UTAUT and flow data was conducted for the data obtained from the MAPS and WHODAS questionnaires scored by participants. Descriptive statistics were calculated for each sub-scale, followed by calculating Cronbach's alpha to evaluate internal reliability. Analysis of covariance (ANCOVA) was used to assess between-group final scores for each sub-scale of questionnaires used with baseline scores as covariate. Mixed analysis of variance (ANOVA) was used to determine any within-subject changes over time. Related *t*-tests confirmed changes at the start and end of the intervention in each group. Between-subject differences (i.e. the effect of intervention) was not interpreted from the mixed ANOVA.

The balance parameters (CoP AP and ML range and SD (mm)) were calculated automatically using the force platform Bioware software package (Raymakers et al., 2005), following which, descriptive statistics were assessed. Post-intervention differences in the CoP AP and ML excursions and velocity and between the groups during bipedal standing were analysed by separate analysis of covariance (ANCOVAs) comparing the post-intervention differences between the groups, with baseline values comprising the covariate. A significance level of 0.05 was used throughout in all analyses and 95% confidence intervals of the differences between the groups' post-intervention scores were calculated.

4.4 Results

This section addresses the research questions related to Aims 1 and 2 (see Chapter 2 on page 57). Data were analysed using version 19.0 of the Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL, USA). Results from ANCOVA, mixed ANOVA, multiple regression, chi squared tests, *t* tests and Wilcoxon's signed-rank tests are presented.

4.4.1 Technology Acceptance

Cronbach's alpha values ranged from 0.65 to 0.98 (see Table 4.4); therefore the variables were deemed to be reliable. Overall, levels of technology acceptance variables increased over time (see Table 4.5 on page 168).

ANCOVA (see Table 4.6 on page 169) showed that intervention had an effect on social influence among older people, $F(1,49) = 5.16$, $p < .01$, $\varepsilon^2 = 0.06$, and behavioural intention, $F(1,49) = 4.99$, $p < .05$, $\varepsilon^2 = 0.08$. Pairwise differences between the adjusted means for post-intervention showed that the control group scored significantly higher in both social influence and behavioural intention after the six-week exercise programme compared to the experimental group (see Table 4.7 on page 170). There was no effect on intervention on performance expectancy, effort expectancy, facilitating conditions and self-efficacy.

Results from the mixed ANOVA showed significant changes over time for all technology acceptance variables (see Table 4.8 on page 171). The largest effect size was seen in behavioural intention, $F(1,46) = 43.96$, $p < 0.001$, $\varepsilon^2 = 0.38$. A paired-samples *t* test indicated that the scores in all of the technology acceptance variables were significantly higher at the end of the intervention than at the beginning for both groups (see Table 4.9 on page 173).

Tests of H_a – H_e. Multiple regression applying the modified UTAUT model showed that the strongest predictors were performance expectancy (PE) and effort expectancy (EE) (see Table 4.10 on page 174). There was a pattern where EE significantly influenced BI in the early stages of the intervention (i.e. at T0 and T1) and then this role was taken over by PE in the later stages (i.e. at T4, T8 and T12). Two-way interactions were mostly not significant except for the model at T1 (PE X Intervention and SI x Intervention) and T12 (SI x Age and Age X Gender).

Tests of H_f – H_g. Hierarchical regression was also applied to the model at four time points (T1, T4, T8 and T12) using previous behavioural intention as a predictor of subsequent behavioural intention (shown earlier at Figure 3.3 at page 72). This model shown at Table 4.11 on page 175 showed that previous behavioural intention significantly predicted future behavioural intention. At T4, T8 and T12, results showed that when previous behavioural intention significantly influenced future behavioural intention, the influence from the other main predictors was no longer there (i.e. they became non-significant except for the significant effect of PE at T1).

Table 4.4: Reliability statistics of technology acceptance variables taken at baseline (T0) and four time points (T1, T4, T8 and T12)

	T0	T1	T4	T8	T12
Performance expectancy	0.97	0.95	0.97	0.97	0.93
Effort expectancy	0.97	0.95	0.96	0.94	0.90
Social influence	0.98	0.97	0.98	0.96	0.94
Facilitating conditions	0.90	0.86	0.89	0.84	0.71
Self-efficacy	0.74	0.74	0.87	0.78	0.65
Behavioural intention	0.97	0.97	0.96	0.98	0.97

Table 4.5: Means and standard deviations of the technology acceptance variables at the following timepoints: T0, T1, T4, T8 and T12.

		Control n = 27		Experimental n = 27	
		Mean	SD	Mean	SD
Performance expectancy	T0	4.16	2.22	3.54	1.56
	T1	4.56	1.97	4.85	1.63
	T4	4.63	1.93	4.91	1.70
	T8	5.67	1.28	5.72	1.47
	T12	6.67	0.48	6.13	1.09
Effort expectancy	T0	4.04	1.95	3.23	1.46
	T1	4.46	1.82	4.31	1.45
	T4	4.75	1.85	4.61	1.35
	T8	5.46	1.39	5.21	1.44
	T12	6.26	0.82	5.70	1.16
Social influence	T0	3.54	2.41	3.19	1.71
	T1	3.66	2.02	3.76	1.74
	T4	4.31	2.09	3.74	1.76
	T8	5.24	1.67	4.25	1.74
	T12	6.13	1.28	4.70	1.84
Facilitating conditions	T0	4.08	2.12	3.77	1.81
	T1	4.28	2.01	4.67	1.80
	T4	4.75	1.93	4.95	1.40
	T8	5.68	1.24	5.35	1.36
	T12	6.21	0.91	5.56	1.29

(Continued on next page)

Table 4.5 – continued from the previous page

		Control		Experimental	
		Mean	SD	Mean	SD
Self-efficacy	T0	3.70	1.93	3.17	1.52
	T1	3.96	1.67	4.07	1.66
	T4	4.64	1.88	4.21	1.59
	T8	5.66	1.20	5.03	1.30
	T12	5.90	1.05	5.22	1.46
Behavioural intention	T0	3.55	2.11	2.88	1.99
	T1	4.44	1.92	4.22	1.70
	T4	4.74	1.74	4.53	1.69
	T8	5.77	1.14	5.62	1.39
	T12	6.58	0.68	5.85	1.47

Table 4.6: Analysis of covariance of technology acceptance variables at T12 with pre-intervention scores as covariate

Source of variation	SS	df	MS	*F*	*p*	ε^2
Performance expectancy						
Pre-measure (P)	2.08	1	2.08	2.87	0.10	0.04
Intervention (I)	0.66	1	0.66	0.92	0.34	-0.002
P x I	0.02	1	0.02	0.03	0.86	-0.02
Error	31.79	44	0.72			
Total	37.11	47				
Effort expectancy						
Pre-measure (P)	6.48	1	6.48	6.98	0.01	0.11
Intervention (I)	1.52	1	1.52	1.64	0.21	0.01
P x I	0.48	1	0.48	0.52	0.48	-0.01
Error	40.87	44	0.93			
Total	50.71	47				
Social influence						
Pre-measure (P)	24.77	1	24.77	11.67	0.001	0.16
Intervention (I)	10.95	1	10.95	5.16	0.03	0.06
P x I	1.65	1	1.65	0.78	0.38	-0.003
Error	93.40	44	2.12			

(Continued on next page)

Table 4.6 – continued from the previous page

Source of variation	SS	df	MS	*F*	*p*	$h_p{}^2$
Total	141.37	47				
Facilitating conditions						
Pre-measure (P)	3.46	1	3.46	2.79	0.10	0.04
Intervention (I)	1.74	1	1.74	1.40	0.24	0.01
P x I	0.22	1	0.22	0.17	0.68	-0.02
Error	54.44	44	1.24			
Total	62.48	47				
Self-efficacy						
Pre-measure (P)	0.14	1	0.14	0.08	0.78	-0.02
Intervention (I)	0.02	1	0.02	0.01	0.93	-0.02
P x I	0.62	1	0.62	0.37	0.55	-0.01
Error	74.51	44	1.69			
Total	79.98	47				
Behavioural intention						
Pre-measure (P)	3.10	1	3.10	2.41	0.13	0.03
Intervention (I)	6.43	1	6.43	4.99	0.03	0.08
P x I	3.03	1	3.03	2.35	0.13	0.03
Error	56.69	44	1.29			
Total	68.41	47				

Table 4.7: Technology acceptance variables from analysis of covariance with pre-intervention scores as covariate, adjusted post-intervention scores and between-group differences for SI and BI

	Control Mean (SE)	Experimental Mean (SE)	Mean difference (SE) 95% CI (*p* value)
Social influence	6.09 (0.30)	4.70 (0.29)	1.39 (0.42) [0.54, 2.24] (0.002)
Behavioural intention	6.57 (0.24)	5.88 (0.23)	0.69 (0.33) [0.03, 1.35] (0.04)

Table 4.8: Mixed analysis of variance for technology acceptance variables

Source of variation	SS	df	MS	*F*	*p*	ε^2
Performance expectancy						
Time	75.27	1	75.27	45.04	0.00	0.36
Time x Intervention	3.32	1	3.32	2.00	0.17	0.01
Error	76.87	46	1.67			
Intervention	0.51	1	0.51	0.23	0.65	-0.01
Error	112.76	46	1.67			
Effort expectancy						
Time	65.00	1	65.00	49.40	0.00	0.37
Time x Intervention	0.59	1	0.59	0.45	0.51	-0.004
Error	60.53	46	1.32			
Intervention	3.30	1	3.30	1001.20	0.00	0.004
Error	116.35	46	2.53			
Social influence						
Time	74.07	1	74.07	42.69	0.00	0.34
Time x Intervention	11.68	1	11.68	6.73	0.01	0.05
Error	79.81	46	1.74			
Intervention	11.36	1	11.36	2.56	0.12	0.03
Error	203.89	46	4.43			
Facilitating conditions						
Time	53.84	1	53.84	28.07	0.00	0.27
Time x Intervention	5.50	1	5.50	2.87	0.10	0.02
Error	88.24	46	1.92			
Intervention	0.44	1	0.44	0.15	0.70	-0.01
Error	135.05	46	2.94			
Self-efficacy						
Time	57.98	1	57.98	26.27	0.00	0.27
Time x Intervention	2.70	1	2.70	1.22	0.27	0.002
Error	101.51	46	2.21			
Intervention	2.05	1	2.05	0.86	0.36	-0.002
Error	109.71	46	2.39			
Behavioural intention						
Time	87.73	1	87.73	43.96	0.00	0.38
Time x Intervention	1.62	1	1.62	0.82	0.37	-0.002

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Table 4.8 – continued from the previous page

Source of variation	SS	df	MS	F	p	η_p^2
Error	91.82	46	2.00			
Intervention	4.89	1	4.89	1.69	0.20	0.01
Error	133.11	46	2.89			

Table 4.9: Differences in technology acceptance variables determined by paired sample's *t* test

	Control n = 27				Experimental n = 27			
	t(df)	*d*	*p*	Mean diff. (SE) 95% CI	*t*(df)	*d*	p	Mean diff. (SE) 95% CI
Performance expectancy	5.46(22)	1.47	0.00	2.14 (0.39) [1.33, 2.96]	3.95(24)	1.04	0.001	1.40 (0.35) [0.67, 2.13]
Effort expectancy	4.93(22)	1.26	0.00	1.80 (0.37) [1.04, 2.56]	5.00(24)	1.16	0.00	1.49 (0.30) [0.88, 2.10]
Social influence	6.28(22)	1.44	0.00	2.46 (0.39) [1.65, 3.27]	2.87(24)	0.61	0.01	1.06 (0.37) [0.30, 1.82]
Facilitating conditions	4.70(22)	1.28	0.00	1.98 (0.42) [1.10, 2.85]	2.68(24)	0.68	0.01	1.02 (0.38) [0.24, 1.80]
Self-efficacy	4.83(22)	1.34	0.00	1.89 (0.39) [1.08, 2.70]	2.67(24)	1.55	0.01	1.22 (0.46) [0.28, 2.16]
Behavioural intention	4.93(22)	1.49	0.00	2.17 (0.44) [1.26, 3.09]	4.39(24)	1.04	0.00	1.65 (0.38) [0.88, 2.43]

d = effect size

Table 4.10: Multiple-regression analysis of the modified Technology Acceptance model (Study 2, N = 54)

	Initial (T0)		T1		T4		T8		T12	
	D only	D+I	D only	D+I	D only	D+I	D only	D+I	D only	D+I
R^2	***0.61	0.59	***0.57	*0.74	***0.82	0.90	***0.83	0.88	***0.79	**0.90
Adj. R^2	0.45	0.39	0.52	0.62	0.79	0.81	0.80	0.79	0.76	0.84
R^2 change		0.77		*0.16		0.07		0.05		*0.11
Constant	***3.34	***3.41	***4.35	***4.26	***4.61	***4.15	***5.61	***5.55	***6.17	***6.32
PE	0.11	-0.26	0.18	-0.39	*0.36	†0.77	***0.50	***0.69	**0.64	0.61
EE	*0.86	*1.22	*0.61	**0.87	0.40	0.19	0.31	0.39	**0.50	*0.34
SI	-0.17	-0.02	0.04	*0.46	*0.22	0.17	0.05	-0.01	0.02	-0.03
Intervention (Int)	0.03	-0.003	-0.07	-0.07	-0.06	-0.12	0.01	0.03	-0.04	-0.15
Age	-0.02	-0.03	-0.03	0.003	-0.01	-0.03	-0.01	-0.03	0.01	-0.02
Gender	0.23	0.20	0.03	0.02	-0.03	-041	-0.14	-0.18	-0.08	-0.14
PE X Gender		-0.32		-0.30		0.36		0.16		-0.12
EE X Gender		0.24		0.32		-0.08		0.31		0.17
SI X Gender		0.31		0.14		-0.14		-0.17		-0.03
PE X Age		0.02		-0.08		0.09		0.01		-0.02
EE X Age		-0.04		-0.03		-0.09		0.003		-0.004
SI X Age		0.02		0.02		-0.02		-0.002		*-0.03
PE X Int		-0.24		*0.53		-0.03		-0.04		0.31
EE X Int		0.44		-0.05		0.47		0.22		0.18
SI X Int		-0.16		**-0.44		-0.23		-0.17		-0.05
Age X Gender		0.01		0.05		-0.06		-0.001		*-0.06

Note: D ONLY: Direct effects only; D+I: Direct effects and interaction terms.
Greyed out cells are not applicable for the specific column.
†. $p = 0.05$ *$p < .05$. **$p < .01$. ***$p < .001$.

Table 4.11: Multiple-regression analysis of the modified Technology Acceptance model 2 (Study 2, N = 54)

	T1			T4			T8			T12		
	D only	D+I	D+II	D only	D+I	D+II	D only	D+I	D+II	D only	D+I	D+II
R^2	***0.60	*0.72	0.75	***0.88	0.91	0.92	***0.78	0.83	0.85	***0.70	0.72	***0.87
Adj. R^2	0.59	0.68	0.68	0.88	0.89	0.89	0.77	0.79	0.69	0.69	0.65	0.82
R^2 change		*0.13	0.02		0.03	0.01		0.06	0.02		0.02	***0.16
Constant	***4.33	***4.24	***4.22	***4.83	***4.94	***4.95	***5.67	***5.73	***5.73	***6.29	***6.25	***6.22
BI at T0	***0.68	***0.51	***0.49									
BI at T3				***0.89	**0.56	*0.47						
BI at T7							***0.76	*0.37	*0.50			
BI at T11										***0.87	**0.88	***0.97
PE		**0.62	***0.62		-0.004	0.08		0.10	0.09		0.00	-0.03
EE		-0.35	-0.28		0.33	0.27		*0.40	0.36		-0.04	-0.10
SI		0.05	0.03		0.07	0.16		-0.05	-0.07		0.04	0.02
Intervention (Int)		0.12	0.13		-0.04	-0.05		-0.06	-0.06		-0.09	-0.17
Age		0.01	-0.004		-0.01	0.001		-0.01	-0.01		0.01	0.03
Gender		-0.17	-0.11		0.13	0.15		0.07	0.06		-0.05	-0.15
BI X Gender			0.05			-0.01			0.12			0.10
BI X Age			-0.03			-0.01			0.002			**-0.07
BI X Int			0.03			0.11			-0.10			**-0.29

Note: D ONLY: Previous BI; D+I: Direct effects only; D+1: Direct effects and interaction terms.
Greyed out cells are not applicable for the specific column.
**p* <.05. ***p* <.01. ****p* <.001.

4.4.2 Flow

The flow variables were deemed reliable due to the range of Cronbach's alpha (0.64 to 0.93) (see Table 4.12). There was an increase of scores over time in all the flow variables (see Table 4.13). Variables that did not meet the homogeneity of regression assumption for ANCOVA (i.e. concentration, clear goals and action-awareness-merging) were analysed using independent measures ANOVA by median split using pre-measures categorised into groups of high and low scores (referred to in the the tables as blocked pre-measure).

Results from the ANCOVA (see Table 4.14 on page 179) showed that there was no effect of intervention on the following flow variables: challenge-skill-balance, unambiguous feedback, transformation of time and loss of consciousness. For autotelic experience and paradox of control, the effect of intervention approached significance, in the direction of an increase in post-intervention scores for these variables. This tentatively suggests that intervention type may influence enjoyment and control in users. A significant effect of intervention, however, was found on concentration at task, $F(1,42) = 4.99$, $p<.05$, $\varepsilon^2 = 0.08$, medium effect, where the direction of effect of intervention was positive for both the experimental and control groups (see Table 4.15 on page 180). Although there were increases in concentration for both the control and experimental groups, the mean score at baseline for concentration was higher in the experimental group.There was no effect of intervention on the remaining flow variables (i.e. clear goals and action-awareness-merging), as determined by the two-way independent measures ANOVA (shown at Table 4.15 on page 180).

Mixed analysis of variance (see Table 4.16 on page 181) showed significant increases over time in all of the flow variables. The largest effect size was seen in unambiguous feedback, $F(1,46) = 63.12$, $p < 0.001$, $\varepsilon^2 = 0.37$. Wilcoxon signed-rank test also showed statistically significant increases in flow level for both groups, where median flow score rating for all the flow variables increased after the intervention (see Table 4.17 on page 183).

Table 4.12: Reliability statistics of flow variables at four time points (T1, T4, T8 and T12)

	T1	T4	T8	T12
Autotelic experience	0.91	0.85	0.82	0.83
Clear goals	0.89	0.89	0.79	0.83
Concentration at task	0.92	0.88	0.79	0.77
Paradox of control	0.93	0.87	0.77	0.89
Challenge-skill-balance	0.79	0.87	0.64	0.79
Unambiguous feedback	0.89	0.89	0.82	0.83
Action-awareness-merging	0.83	0.82	0.75	0.90
Transformation of time	0.78	0.83	0.87	0.93
Loss of self-consciousness	0.90	0.90	0.79	0.76

Table 4.13: Means and standard deviations of the flow variables at T1, T4, T8 and T12

		Control		Experimental	
		Mean	SD	Mean	SD
Autotelic experience	T1	3.00	1.43	3.41	1.28
	T4	3.26	1.11	3.44	1.01
	T8	3.84	0.77	3.81	0.86
	T12	4.16	0.54	4.10	0.80
Clear goals	T1	3.05	1.27	2.92	1.25
	T4	3.22	1.12	3.57	0.98
	T8	3.86	0.71	4.00	0.72
	T12	4.53	0.46	4.36	0.79

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Table 4.13 – continued from the previous page

		Control		Experimental	
		Mean	SD	Mean	SD
Concentration at task	T1	2.96	1.22	3.31	1.26
	T4	3.15	0.93	3.60	1.19
	T8	3.80	0.69	3.80	0.82
	T12	4.53	0.44	4.31	0.74
Paradox of control	T1	2.82	1.36	2.84	1.24
	T4	3.25	0.91	2.99	1.04
	T8	3.88	0.81	3.86	0.72
	T12	4.40	0.66	4.08	1.01
Challenge-skill-balance	T1	2.93	1.06	3.04	1.01
	T4	3.24	1.02	3.01	0.92
	T8	3.97	0.58	3.76	0.59
	T12	4.42	0.51	4.07	0.76
Unambiguous feedback	T1	2.81	1.26	2.91	1.12
	T4	3.03	1.05	3.11	1.10
	T8	3.82	0.79	3.90	0.68
	T12	4.41	0.62	4.21	0.76
Action-awareness-merging	T1	2.46	1.03	2.67	1.01
	T4	2.82	0.95	2.72	0.80
	T8	3.66	0.73	3.61	0.75
	T12	4.09	1.02	3.89	0.84
Transformation of time	T1	2.55	1.16	3.05	1.21
	T4	2.82	0.94	2.78	1.14
	T8	3.47	1.03	3.46	0.99
	T12	3.75	1.28	3.56	1.19
Loss of self-consciousness	T1	3.09	1.42	3.31	1.25
	T4	3.47	0.93	3.54	1.20
	T8	3.99	0.74	4.08	0.82
	T12	4.52	0.56	4.40	0.74

Table 4.14: Analysis of covariance for flow dimensions

Source of variation	SS	df	MS	*F*	*p*	ε^2
Autotelic experience						
Pre-measure (P)	9.19	1	9.19	32.90	0.00	0.40
Intervention (I)	1.13	1	1.13	4.06	0.05	0.04
P x I	0.84	1	0.84	3.02	0.09	0.03
Error	12.28	44	0.28			
Total	22.00	47				
Challenge-skill-balance						
Pre-measure (P)	0.54	1	0.54	1.31	0.26	0.01
Intervention (I)	1.33	1	1.33	3.21	0.08	0.04
P x I	0.62	1	0.62	1.50	0.23	0.01
Error	18.19	44	0.41			
Total	20.87	47				
Paradox of control						
Pre-measure (P)	1.34	1	1.34	1.88	0.18	0.02
Intervention (I)	2.59	1	2.59	3.63	0.06	0.06
P x I	1.68	1	1.68	2.35	0.13	0.03
Error	31.30	44	0.71			
Total	35.43	47				
Unambiguous feedback						
Pre-measure (P)	0.80	1	0.80	1.67	0.20	0.01
Intervention (I)	0.94	1	0.94	1.96	0.17	0.02
P x I	0.59	1	0.59	1.24	0.27	0.01
Error	21.10	44	0.48			
Total	22.91	47				
Transformation of time						
Pre-measure (P)	9.69	1	9.69	1.87	0.18	0.20
Intervention (I)	10.81	1	10.81	2.09	0.16	-0.01
P x I	5.86	1	5.86	1.13	0.29	-0.01
Error	227.83	44	5.18			
Total	245.06	47				
Loss of consciousness						
Pre-measure (P)	0.93	1	0.93	2.18	0.15	0.02
Intervention (I)	0.55	1	0.55	1.29	0.26	0.01

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Table 4.14 – continued from the previous page

Source of variation	SS	df	MS	F	p	ε^2
P x I	0.37	1	0.37	0.87	0.36	-0.003
Error	18.77	44	0.43			
Total	20.17	47				

Table 4.15: Two way ANOVA for concentration at task, clear goals and action-awareness-merging

Source	SS	df	MS	F	p	ε^2
Concentration at task						
Intervention (I)	1.79	1	1.79	4.99	0.03	0.08
Blocked pre-measure (B)	0.14	2	0.07	0.19	0.83	-0.03
I x B	1.97	2	0.98	2.73	0.08	0.07
Error	15.11	42	0.36			
Total	18.04	47				
Clear goals						
Intervention (I)	0.48	1	0.48	1.25	0.27	0.005
Blocked pre-measure (B)	1.52	1	1.52	3.95	0.05	0.06
I x B	1.13	1	1.13	2.95	0.09	0.04
Error	16.91	44	0.38			
Total	20.16	47				
Action-awareness-merging						
Intervention (I)	0.41	1	0.41	0.47	0.50	-0.01
Blocked pre-measure (B)	0.99	1	0.99	1.16	0.29	0.003
I x B	1.26	1	1.26	1.47	0.23	0.01
Error	37.62	44	0.86			
Total	40.43	47				

Table 4.16: Mixed analysis of variance for flow variables

Source of variation	SS	df	MS	*F*	*p*	ε^2
Autotelic experience						
Time	22.85	1	22.85	40.20	0.00	0.23
Intervention x time	0.83	1	0.83	1.47	0.23	0.003
Error	26.14	46	0.57			
Intervention	0.37	1	0.37	0.21	0.65	-0.01
Error	80.97	46	1.76			
Clear goals						
Time	51.01	1	51.01	69.50	0.00	0.16
Intervention x time	0.01	1	0.01	0.01	0.91	-0.001
Error	33.76	47	0.73			
Intervention	0.56	1	0.56	0.44	0.51	0.01
Error	59.00	46	1.28			
Challenge-skill-balance						
Time	37.93	1	37.93	57.69	0.00	0.32
Intervention x time	0.94	1	0.94	1.43	0.24	0.002
Error	30.25	46	0.66			
Intervention	0.58	1	0.58	0.65	0.42	-0.003
Error	40.97	46	0.89			
Concentration at task						
Time	41.54	1	41.54	49.27	0.00	0.32
Intervention x time	1.23	1	1.23	1.46	0.23	-0.003
Error	38.78	46	0.84			
Intervention	0.00	1	0.001	0.00	0.99	-0.01
Error	51.77	46	1.13			
Paradox of control						
Time	47.60	1	47.60	47.46	0.00	0.33
Intervention x time	0.15	1	0.15	0.15	0.70	-0.01
Error	46.14	46	1.00			
Intervention	1.41	1	1.41	0.99	0.33	-0.0001
Error	65.50	46	1.42			
Unambiguous feedback						
Time	50.43	1	50.43	63.12	0.00	0.37
Intervention x time	0.12	1	0.12	0.15	0.70	-0.005
Error	36.75	46	0.80			

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Table 4.16 – continued from the previous page

Source of variation	SS	df	MS	F	p	ε^2
Intervention	0.42	1	0.42	0.38	0.54	-0.01
Error	50.35	46	1.10			
Action-awareness-merging						
Time	48.12	1	48.12	56.01	0.00	0.35
Intervention x time	0.45	1	0.45	0.53	0.47	-0.003
Error	39.52	46	0.86			
Intervention	0.09	1	0.09	0.08	0.78	-0.01
Error	47.87	46	1.04			
Transformation of time						
Time	17.35	1	17.35	21.96	0.00	0.16
Intervention x time	2.17	1	2.17	2.75	0.10	0.01
Error	36.36	46	0.79			
Intervention	0.30	1	0.30	0.13	0.72	-0.02
Error	101.95	46	2.22			
Loss of consciousness						
Time	39.01	1	39.01	41.39	0.00	0.29
Intervention x time	0.38	1	0.38	0.40	0.53	-0.004
Error	43.36	46	0.94			
Intervention	0.00	1	0.00	0.00	0.99	-0.01
Error	60.24	46	1.31			

Table 4.17: Differences in flow levels at the start and end of the intervention, as determined by Wilcoxon's signed-rank test (N = 54)

	Control						Experimental					
	Median_{Start}	Median_{End}	Z	p	r_{Start}	r_{End}	Median_{Start}	Median_{End}	Z	p	r_{Start}	r_{End}
ENJY	3.00	4.00	-3.38	0.00	-0.68	-0.70	3.50	4.25	-3.39	0.00	-0.65	-0.68
GOAL	2.75	4.75	-2.90	0.002	-0.58	-0.60	3.00	4.75	-4.14	0.00	-0.80	-0.83
CHAL	3.25	4.50	-3.68	0.00	-0.74	-0.77	3.25	4.25	-3.63	0.00	-0.70	-0.73
CONC	2.75	4.75	-3.60	0.00	-0.72	-0.75	3.50	4.50	-3.59	0.00	-0.69	-0.72
CONT	2.75	4.50	-3.53	0.00	-0.71	-0.74	3.00	4.25	-3.75	0.00	-0.72	-0.75
FDBK	2.50	4.50	-3.70	0.00	-0.74	-0.77	3.00	4.50	-4.08	0.00	-0.79	-0.82
ACT	2.25	4.50	-3.45	0.00	-0.69	-0.72	2.50	4.00	-4.08	0.00	-0.79	-0.82
TRAN	2.00	4.00	-2.28	0.02	-0.46	-0.48	3.25	4.00	-2.38	0.02	-0.46	-0.48
LOSS	2.75	4.75	-3.33	0.00	-0.67	-0.69	3.50	4.50	-3.50	0.00	-0.67	-0.70

Note. ENJY = autotelic experience. GOAL = clear goals. CHAL = challenge-skill-balance. CONC = concentration at task. CONT = paradox of control. FDBCK = unambiguous feedback. ACT = action-awareness-merging. TRAN = transformation of time. LOSS = loss of self-consciousness.

4.4.3 Pain categories, prevalence and intensity

Most of the participants had unspecified chronic pain (Class 4). For example, back pain rated as 5 on a scale of 0–10 with 10 being the worst possible pain, is a single site pain in Class 4. Two participants had multiple pain sites (Class 1) (see Appendix H on page 355). The prevalence of pain in body locations is shown in Appendix H on page 355 and 356. The back, hips and hands/wrists were the most frequently reported sites of pain. Pain experienced during various activities is shown at Appendix H on page 356. Participants reported having experienced the most pain while walking on stairs. Overall self-reported pain intensity experienced at the start and end of the intervention is presented at Table 4.18 on page 185.

No effect of intervention was found on self-reported pain intensity experienced within 30 days before and after the intervention, as determined by the ANCOVA with pre-measures as the covariate (see Table 4.19). Self-reported pain intensity which was measured at the start and end of the intervention did not meet the homogeneity of variances test, and was analysed by two-way independent measures ANOVA with blocking using median splits of scored pre-measures (see Table 4.20). No effect of intervention on self-reported pain intensity was found by the two-way ANOVA by blocking. There was also no effect of time on pain intensity, as determined by the mixed ANOVA (see Table 4.21). A paired-samples *t*-test indicated that overall self-reported pain intensity experienced assessed after the intervention was significantly reduced in the experimental group (M = 2.07, SD = 2.11) compared to the control group (M = 3.48, SD = 3.03), $t(26) = -2.88$, $p < .01$, $d = -0.45$ (see Table 4.22 on page 187).

Table 4.18: Overall pain intensity experienced at the start and end of the intervention

	Pain intensity*		Pain intensity**	
N = 54	Start	End	Start	End
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Control	6.00 (2.34)	5.85 (2.43)	3.33 (2.82)	3.48 (3.03)
Experimental	5.52 (2.24)	5.04 (2.21)	2.96 (1.87)	2.07 (2.11)

* Pain intensity experienced within 30 days
** Pain intensity experienced at testing

Table 4.19: Analysis of covariance for pain intensity experienced before and after the intervention

Source of variation	SS	df	MS	F	p	ε^2
Pain intensity**						
Pre-measure (P)	151.66	1	151.66	43.26	0.00	0.39
Intervention (I)	5.29	1	5.29	1.51	0.23	0.005
P x I	0.01	1	0.01	0.002	0.97	-0.009
Error	175.30	50	3.51			
Total	381.33	53				

** Self-reported pain intensity experienced at testing

Table 4.20: Two way ANOVA for pain intensity experienced within 30 days before and after the intervention

Source	SS	df	MS	F	p	ε^2
Pain intensity*						
Intervention (I)	1.31	1	1.31	0.48	0.49	-0.005
Blocked pre-measure (B)	137.98	2	68.99	25.09	0.00	0.46
I x B	13.79	2	6.90	2.51	0.09	0.03
Error	132.00	48	2.75			
Total	289.33	53				

Note. *Self-reported pain intensity within 30 days before testing.

Table 4.21: Mixed analysis of variance for pain intensity

Source of variation		SS	df	MS	*F*	*p*	ε^2
Pain intensity*							
	Time	2.68	1	2.68	2.11	0.15	0.002
	Intervention x time	0.75	1	0.75	0.59	0.45	-0.001
	Error	66.07	52	1.27			
	Intervention	11.34	1	11.34	1.21	0.28	0.003
	Error	487.04	52	9.37			
Pain intensity**							
	Time	3.70	1	3.70	2.03	0.16	-0.003
	Intervention x time	7.26	1	7.26	3.97	0.05	-0.008
	Error	95.04	52	1.83			
	Intervention	21.33	1	21.33	1.99	0.16	0.02
	Error	556.52	52	10.70			

* Pain intensity experienced within 30 days

** Pain intensity experienced at testing

Table 4.22: Pain intensity difference in each group determined by paired sample's *t* test (N = 54)

	Control				Experimental			
	t(df)	*d*	*p*	Mean (SE) 95% CI	*t*(df)	*d*	*p*	Mean (SE) 95% CI
Pain intensity*	-0.85(26)	-0.06	0.40	-0.15 (0.18) [-0.51, 0.21]	-1.21(26)	-0.22	0.24	-0.48 (0.40) [-1.30, 0.34]
Pain intensity**	0.35(26)	0.05	0.73	0.15 (0.42) [-0.71, 1.01]	-2.88(26)	-0.45	0.01	-0.89 (1.60) [-1.52, -0.26]

Note. *Pain intensity within 30 days before testing.
Note. **Pain intensity on the day of testing.

4.4.4 Multidimentional Affect and Pain Survey (MAPS)

Reliability analyses showed that 10 clusters from the somatosensory supercluster were found to be trustworthy. This was the same for 6 clusters from the emotional supercluster and 3 clusters from the well-being supercluster. The MAPS clusters that were shown to have satisfactory reliability with Cronbach's alpha presented values ranging from 0.66 to 0.93 (see Table 4.23). Clusters that did not show internal reliability (i.e. temporal pain, faint pain, muscle/joint pain, mental distress, respiratory distress, cold pain, pain restriction, anxiety, emotional avoidance, treatable illness and mentally engaging - Cronbach's alpha < 0.66) were not included in the analysis.

The descriptive statistics for the MAPs clusters are presented at Table 4.24 on page 191. Although no effect of intervention was found on most of the pain variables analysed by ANCOVA, the effect of invention on physically engaged (from the well-being supercluster) approached significance, tentatively suggesting that there were increases in older people's feelings of being active and vigorous after the intervention (shown at Table 4.25 on page 193).

The two-way ANOVA by blocking (i.e. using median split of pre-measures categorized into high and low scores) showed that intervention had an effect on thermal pain $F(1,48) = 14.43$, $p<0.001$, $\varepsilon^2 = 0.09$ (small effect) (see table 4.27 on page 200). The significant reduction in thermal pain scores suggest an improvement in older people's heat-related pain experience (e.g. burning pain, site of pain feeling hot) (see Table 4.28 on page 200).

The mixed ANOVA showed that there were significant differences over time between pre- and post- intervention scores in depressed mood, F(1,50) = 9.09, p$<$.01, ε^2 = 0.01 (small effect); and affiliative feelings, F(1,50) = 6.92, p$<$.05, ε^2 = 0.03 (medium effect) where the direction of effect was positive for these variables (see Table 4.26 on page 196). Examination of the means showed that although there were significant reductions in depressed mood for both the control and experimental groups, the change was larger in the experimental group. The increase in affiliative feelings for the experimental group was also larger than those of the control group.

The effect of time approached significance for two variables, physically engaged, F(1,50) = 3.82, p =.06, ε^2 = 0.01 (small effect); and anger, F(1,50) = 3.76, p =.06, ε^2 = 0.01 (small effect). This tentatively suggested that participants from both groups felt more active and vigorous over time. While the means showed that there was an decrease in feelings of anger, outrage, upset and annoyance over time for both groups, the decrease was larger in the experimental group compared to those of the control group.

Table 4.23: Reliability statistics for MAPS clusters

	Cronbach's α	
	Start	End
Somatosensory		
Cutaneous *(itchy, irritating, crawling, tickling, tingling)*	0.66	0.68
Autonomic distress *(disgusting, nauseating)*	0.81	0.83
Thermal *(burning, hot)*	0.63	0.76
Pain extent *(spreading, persistent, worsening, pervasive)*	0.72	0.73

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Table 4.23 – continued from previous page

	Cronbach's α Start	End
Intense pain qualities *(vicious, excruciating, nasty, overwhelming)*	0.89	0.91
Intermittent pressure *(throbbing, pounding)*	0.72	0.70
Brightness *(stinging, smarting)*	0.71	0.85
Incisive pressure *(sharp, shooting, biting, deep, tearing, stabbing, gnawing)*	0.86	0.87
Traction/abrasion *(pulling, grinding, squeezing, pressing, cramping, tugging, crushing)*	0.84	0.89
Numb *(numb, numbing)*	0.81	0.85
Emotional pain		
Physical illness *(ailing, suffering)*	0.67	0.69
Depressed mood *(lousy, rejected, depressed, discouraged, miserable, lonely)*	0.75	0.80
Self-blame *(guilty, negligent)*	0.84	0.87
Anger *(angry, outraged, upset, annoyed)*	0.84	0.87
Fear *(alarming, startling, frantic, terrified)*	0.81	0.82
Physical avoidance *(exhausting, sleepy, tiring, sluggish)*	0.79	0.77
Well-being		
Physically engaged *(active, vigorous)*	0.75	0.69
Affiliative feelings *(loved, forgiving, affectionate, sympathetic)*	0.85	0.89
Positive affect *(hopeful, happy, relaxed, encouraged, cheerful, satisfied, calm)*	0.92	0.93

Table 4.24: Means and standard deviations for MAPS clusters

	Before				After			
	Control		Experimental		Control		Experimental	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Somatosensory								
Cutaneous *(itchy, irritating, crawling, tickling, tingling)*	1.13	1.00	0.67	0.53	1.08	1.05	0.63	0.51
Autonomic distress *(disgusting, nauseating)*	0.80	1.37	0.09	0.24	0.67	1.35	0.19	0.49
Thermal *(burning, hot)*	1.41	1.80	0.93	1.30	1.25	1.78	0.56	0.97
Pain extent *(spreading, persistent, worsening, pervasive)*	2.00	1.52	1.29	0.99	1.80	1.59	1.29	1.03
Intense pain qualities *(vicious, excruciating, nasty, overwhelming)*	2.12	1.79	0.98	1.16	1.91	1.84	0.87	1.20
Intermittent pressure *(throbbing, pounding)*	1.46	1.74	0.63	1.11	1.27	1.69	0.71	1.28
Brightness *(stinging, smarting)*	0.56	1.19	0.07	1.18	0.63	1.27	0.19	0.49
Incisive pressure *(sharp, shooting, biting, deep, tearing, stabbing, gnawing)*	1.68	1.32	0.20	0.62	1.53	1.28	0.84	0.81
Traction/abrasion *(pulling, grinding, squeezing, pressing, cramping, tugging, crushing)*	1.12	1.31	0.26	0.70	0.96	1.28	0.54	0.92
Numb *(numb, numbing)*	1.28	1.84	0.64	0.68	1.13	1.74	0.40	0.92

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Table 4.24 – continued from previous page

	Before				After			
	Control		Experimental		Control		Experimental	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Emotional pain								
Physical illness *(ailing, suffering)*	1.61	1.38	0.57	0.76	1.38	1.42	0.90	0.88
Depressed mood *(lousy, rejected, depressed, discouraged, miserable, lonely)*	0.91	0.99	1.35	1.11	0.74	0.90	0.40	0.45
Self-blame *(guilty, negligent)*	0.48	0.90	1.24	1.12	0.52	1.04	0.40	0.74
Anger *(angry, outraged, upset, annoyed)*	0.83	1.32	2.67	1.36	0.65	1.19	0.43	0.66
Fear *(alarming, startling, frantic, terrified)*	0.78	1.34	0.26	0.46	0.69	1.26	0.13	0.36
Physical avoidance *(exhausting, sleepy, tiring, sluggish)*	2.14	1.50	1.24	1.12	1.83	1.40	1.13	1.00
Well-being								
Physically engaged *(active, vigorous)*	2.46	1.65	2.28	1.56	2.69	1.49	2.62	1.42
Affiliative feelings *(loved, forgiving, affectionate, sympathetic)*	3.41	1.44	2.71	1.30	3.57	1.40	3.14	1.40
Positive affect *(hopeful, happy, relaxed, encouraged, cheerful, satisfied, calm)*	3.11	1.51	2.74	1.15	3.32	1.04	2.90	0.94

Table 4.25: Analysis of covariance for MAPS clusters

Source of variation	SS	df	MS	*F*	*p*	ε^2
Somatosensory						
Cutaneous						
Pre-measure (P)	18.27	1	18.27	192.37	0.00	0.49
Intervention (I)	0.01	1	0.01	0.12	0.73	-0.002
P x I	0.04	1	0.04	0.45	0.51	-0.001
Error	4.56	48	0.10			
Total	36.73	51				
Autonomic distress						
Pre-measure (P)	5.50	1	5.50	33.88	0.00	0.10
Intervention (I)	0.20	1	0.20	1.25	0.27	0.001
P x I	0.008	1	0.008	0.05	0.82	-0.003
Error	7.79	48	0.16			
Total	54.51	51				
Pain extent						
Pre-measure (P)	50.87	1	50.87	115.43	0.00	0.54
Intervention (I)	0.56	1	0.56	1.27	0.27	0.001
P x I	0.59	1	0.59	1.34	0.25	0.002
Error	21.15	48	0.44			
Total	93.22	51				
Intense pain qualities						
Pre-measure (P)	60.84	1	60.84	71.69	0.00	0.45
Intervention (I)	0.05	1	0.05	0.05	0.82	-0.01
P x I	0.59	1	0.59	0.69	0.41	-0.002
Error	40.73	48	0.85			
Total	134.80	51				
Intermittent pressure						
Pre-measure (P)	39.71	1	39.71	34.29	0.00	0.33
Intervention (I)	0.65	1	0.65	0.56	0.46	-0.004
P x I	1.10	1	1.10	0.95	0.34	-0.001
Error	55.59	48	1.16			
Total	116.25	51				
Brightness						
Pre-measure (P)	4.13	1	4.13	13.99	0.00	0.08
Intervention (I)	0.01	1	0.01	0.04	0.84	-0.01

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Table 4.25 – continued from the previous page

Source of variation	SS	df	MS	*F*	*p*	ε^2
P x I	0.13	1	0.13	0.46	0.50	-0.003
Error	14.15	48	0.30			
Total	48.86	51				
Incisive pressure						
Pre-measure (P)	21.99	1	21.99	43.39	0.00	0.34
Intervention (I)	0.12	1	0.12	0.24	0.63	-0.01
P x I	0.02	1	0.02	0.05	0.83	-0.01
Error	24.33	48	0.51			
Total	63.80	51				
Traction/abrasion						
Pre-measure (P)	30.57	1	30.57	72.20	0.00	0.47
Intervention (I)	0.20	1	0.20	0.47	0.50	-0.003
P x I	1.21	1	1.21	2.85	0.10	0.01
Error	20.32	48	0.42			
Total	64.70	51				
Numb						
Pre-measure (P)	30.33	1	30.33	47.70	0.00	0.29
Intervention (I)	0.14	1	0.14	0.22	0.64	-0.005
P x I	0.01	1	0.01	0.02	0.89	-0.01
Error	30.52	48	0.64			
Total	103.73	51				
Emotional pain						
Self-blame						
Pre-measure (P)	32.17	1	32.17	219.37	0.00	0.78
Intervention (I)	0.01	1	0.01	0.07	0.79	-0.003
P x I	0.14	1	0.14	0.95	0.34	-0.002
Error	7.04	48	0.15			
Total	40.92	51				
Anger						
Pre-measure (P)	21.14	1	21.14	68.09	0.00	0.44
Intervention (I)	0.004	1	0.004	0.01	0.91	-0.01
P x I	0.15	1	0.15	0.47	0.50	-0.003
Error	14.90	48	0.31			
Total	46.84	51				

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Table 4.25 – continued from the previous page

Source of variation	SS	df	MS	*F*	*p*	ε^2
Fear						
Pre-measure (P)	7.90	1	7.90	28.51	0.00	0.16
Intervention (I)	0.04	1	0.04	0.13	0.73	-0.01
P x I	0.38	1	0.38	1.38	0.25	0.002
Error	13.30	48	0.28			
Total	46.74	51				
Physical avoidance						
Pre-measure (P)	43.32	1	43.32	78.73	0.00	0.53
Intervention (I)	0.01	1	0.01	0.02	0.90	-0.01
P x I	0.20	1	0.20	0.37	0.55	-0.004
Error	26.41	48	0.55			
Total	80.23	51				
Well-being						
Physically engaged						
Pre-measure (P)	76.16	1	76.16	132.37	0.00	0.71
Intervention (I)	2.16	1	2.16	3.76	0.06	0.01
P x I	2.10	1	2.10	3.64	0.06	0.01
Error	27.62	48	0.58			
Total	106.27	51				
Affiliative feelings						
Pre-measure (P)	67.62	1	67.62	120.42	0.00	0.67
Intervention (I)	1.25	1	1.25	2.22	0.14	0.01
P x I	0.91	1	0.91	1.62	0.21	0.003
Error	26.96	48	0.56			
Total	100.17	51				
Positive affect						
Pre-measure (P)	23.45	1	23.45	46.97	0.00	0.45
Intervention (I)	0.00	1	0.00	0.00	0.99	-0.01
P x I	0.06	1	0.06	0.12	0.73	-0.01
Error	23.96	48	0.50			
Total	51.35	51				

Table 4.26: Mixed analysis of variance for MAPS clusters

Source of variation	SS	df	MS	*F*	*p*	ε^2
Somatosensory						
Cutaneous						
Time	0.003	1	0.003	0.07	0.15	0.001
Time x Intervention	0.00	1	0.00	0.00	1.00	-0.001
Error	2.34	50	0.05			
Intervention	5.18	1	5.18	4.01	0.05	0.07
Error	64.52	50	1.29			
Autonomic distress						
Time	0.00	1	0.00	0.00	1.00	-0.001
Time x Intervention	0.24	1	0.24	3.00	0.09	0.003
Error	4.01	50	0.08			
Intervention	8.65	1	8.65	4.43	0.04	0.12
Error	97.63	50	1.95			
Thermal						
Time	1.39	1	1.39	3.85	0.06	0.01
Time x Intervention	0.62	1	0.62	1.71	0.20	0.004
Error	18.00	50	0.36			
Intervention	7.54	1	7.54	1.81	0.19	0.05
Error	208.42	50	4.17			
Pain extent						
Time	0.32	1	0.32	1.42	0.24	0.001
Time x Intervention	0.10	1	0.10	0.45	0.51	-0.002
Error	11.24	50	0.23			
Intervention	8.51	1	8.51	2.64	0.11	0.08
Error	161.57	50	3.23			
Intense pain qualities						
Time	0.65	1	0.65	1.45	0.23	0.003
Time x Intervention	0.05	1	0.05	0.11	0.74	-0.01
Error	22.58	50	0.45			
Intervention	30.97	1	30.97	7.17	0.01	0.36
Error	215.84	50	4.32			
Intermittent pressure						
Time	0.09	1	0.09	0.13	0.72	-0.007
Time x Intervention	0.78	1	0.78	1.18	0.28	0.001

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Table 4.26 – continued from the previous page

Source of variation	SS	df	MS	*F*	*p*	ε^2
Error	32.89	50	0.66			
Intervention	13.89	1	13.89	3.68	0.06	0.12
Error	188.83	50	3.78			
Brightness						
Time	0.24	1	0.24	1.66	0.20	0.002
Time x Intervention	0.01	1	0.01	0.07	0.80	-0.002
Error	7.25	50	0.15			
Intervention	5.54	1	5.54	3.62	0.06	0.07
Error	76.58	50	1.53			
Incisive pressure						
Time	0.21	1	0.21	0.77	0.39	-0.001
Time x Intervention	0.03	1	0.03	0.11	0.74	-0.004
Error	13.66	50	0.27			
Intervention	13.56	1	13.56	6.77	0.01	0.18
Error	100.13	50	2.00			
Traction/abrasion						
Time	0.10	1	0.10	0.46	0.50	-0.002
Time x Intervention	0.17	1	0.17	0.74	0.40	-0.001
Error	11.19	50	0.22			
Intervention	6.43	1	6.43	3.07	0.09	0.07
Error	104.77	50	2.10			
Numb						
Time	0.02	1	0.02	0.06	0.80	-0.005
Time x Intervention	0.70	1	0.70	2.05	0.16	0.005
Error	16.91	50	0.34			
Intervention	20.79	1	20.79	5.81	0.02	0.25
Error	178.97	50	3.58			
Emotional						
Physical illness						
Time	0.47	1	0.47	2.09	0.15	0.004
Time x Intervention	0.01	1	0.01	0.04	0.84	-0.003
Error	11.27	50	0.23			
Intervention	6.50	1	6.50	2.56	0.12	0.06
Error	127.10	50	2.54			

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Table 4.26 – continued from the previous page

Source of variation	SS	df	MS	F	p	ε^2
Depressed mood						
Time	0.64	1	0.64	9.09	0.004	0.01
Time x Intervention	0.10	1	0.10	1.37	0.25	0.0005
Error	3.53	50	0.07			
Intervention	2.12	1	2.12	1.92	0.17	0.02
Error	55.12	50	1.10			
Self-blame						
Time	0.002	1	0.002	0.03	0.86	-0.001
Time x Intervention	0.002	1	0.002	0.03	0.86	-0.001
Error	3.62	50	0.07			
Intervention	0.29	1	0.29	0.20	0.66	-0.02
Error	73.64	50	1.47			
Anger						
Time	0.74	1	0.74	3.76	0.06	0.01
Time x Intervention	0.001	1	0.001	0.003	0.96	-0.003
Error	9.79	50	0.20			
Intervention	1.33	1	1.33	0.69	0.45	-0.01
Error	95.89	50	1.92			
Fear						
Time	0.41	1	0.41	2.42	0.14	0.004
Time x Intervention	0.002	1	0.002	0.01	0.91	-0.003
Error	8.40	50	0.17			
Intervention	7.81	1	7.81	4.57	0.04	0.10
Error	85.44	50	1.71			
Emotional avoidance						
Time	0.002	1	0.002	0.01	0.92	-0.004
Time x Intervention	0.12	1	0.12	0.54	0.47	-0.002
Error	11.01	50	0.22			
Intervention	0.70	1	0.70	0.28	0.60	-0.03
Error	123.87	50	2.48			
Physical avoidance						
Time	0.82	1	0.82	2.61	0.11	0.008
Time x Intervention	0.03	1	0.03	0.09	0.76	-0.004
Error	15.74	50	0.32			

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Table 4.26 – continued from the previous page

Source of variation	SS	df	MS	F	p	ε^2
Intervention	13.70	1	13.70	4.86	0.03	0.16
Error	140.89	50	2.82			
Well-being						
Physically engaged						
Time	1.39	1	1.39	3.82	0.06	0.01
Time x Intervention	0.24	1	0.24	0.66	0.42	-0.002
Error	18.13	50	0.36			
Intervention	0.78	1	0.78	0.18	0.67	-0.05
Error	215.82	50	4.32			
Affiliative feelings						
Time	2.09	1	2.09	6.92	0.01	0.03
Time x Intervention	0.51	1	0.51	1.67	0.20	0.003
Error	15.12	50	0.30			
Intervention	8.23	1	8.23	2.27	0.14	0.07
Error	180.86	50	3.62			
Positive affect						
Time	0.49	1	0.49	1.14	0.29	0.001
Time x Intervention	0.02	1	0.02	0.06	0.82	-0.006
Error	21.31	50	0.43			
Intervention	5.14	1	5.14	2.24	0.14	0.04
Error	114.68	50	2.29			

Table 4.27: MAPS independent measures ANOVA by blocking for thermal pain, depressed mood and physical illness

Source	SS	df	MS	*F*	*p*	ε^2
Thermal pain						
Intervention (I)	10.10	1	10.10	14.43	0.00	0.09
Blocked pre-measure (B)	53.84	1	53.84	76.87	0.00	0.49
I x B	9.54	1	9.54	13.62	0.001	0.08
Error	33.62	48	7.00			
Total	109.52	51				
Depressed mood						
Intervention (I)	1.20	1	1.20	2.98	0.09	0.03
Blocked pre-measure (B)	6.03	1	6.03	15.00	0.00	0.21
I x B	0.26	1	0.26	0.64	0.43	-0.005
Error	19.29	48	0.40			
Total	27.13	51				
Physical illness						
Intervention (I)	0.12	1	0.12	0.18	0.68	-0.008
Blocked pre-measure (B)	29.56	1	29.56	43.48	0.00	0.39
I x B	0.31	1	0.31	0.46	0.50	-.005
Error	32.63	48	0.68			
Total	73.17	51				

Table 4.28: Pairwise comparisons with estimates of post-intervention scores and between-group differences for thermal pain, depressed mood and physical illness

	Control Mean (SE)	Experimental Mean (SE)	Mean difference (SE) 95% CI (*p* value)
Thermal pain	2.05 (0.19)	0.99 (0.21)	-1.06 (0.28) [-1.62, -0.50] (0.00)
Depressed mood	1.40 (0.23)	0.83 (0.23)	-0.57 (0.33) [-1.23, 0.09] (0.09)
Physical illness	1.73 (0.17)	1.60 (0.25)	-0.13 (0.31) [-0.74, 0.49] (0.68)

4.4.5 WHO Disability Assessment Schedule 2.0

Cronbach's alpha values estimated from the World Health Organization Disability Assessment Schedule (WHODAS) domains ranged between 0.61 and 0.89 (see Table 4.29). Descriptive statistics for data recorded at the start and end of the intervention are shown at Table 4.30. Participants in the control group scored the highest for the participation in the society domain, while lower scores were reported for self-care for both groups. Most post-intervention scores for life activities were lower in the experimental group, implying less difficulty in this domain, while there was no change in scores for the control group.

No effect of intervention was found on the other WHODAS domains (i.e. understanding and communicating, getting around and self care), as determined by the ANCOVA with pre-measures as the covariate (see Table 4.31 on page 203). The domains (i.e. getting along with people, life activities and participation in society) that did not meet the homogeneity of variances test were analysed by two-way independent measures ANOVA with blocking using median splits of scored pre-measures (see Table 4.32 on page 204). Categorised pre-measures for these domains were grouped into two levels, either high or low. The two-way independent measures ANOVA with blocking showed that there was a significant interaction between intervention and the blocked pre-measure of getting along with people, $F(1,47) = 8.80$, $p < .05$, $\varepsilon^2 = 0.09$ (medium effect) where the direction of interaction was opposite. There was an increase in mean for the control group (i.e. more dfficulty) whereas the mean for the experimental group was reduced. Pairwise comparisons showed a significant reduction in scores in the experimental group (see Table 4.33), suggesting an improvement (i.e. less difficulty) in older people's involvement in community, social and civic life after exergaming.

The mixed ANOVA did not find any significant effect of time on all of the WHODAS domains (see Table 4.34 on page 205). Paired sample's t test also showed that there were no significant group differences in the WHODAS domains for the start and end of the intervention (see Table 4.35 on page 207).

Table 4.29: Reliability statistics of WHODAS domains

Domain	Cronbach's alpha	
	Start	End
Understanding and communicating	0.88	0.88
Getting around	0.89	0.82
Self care	0.74	0.73
Getting along with people	0.61	0.67
Life activities (household)	0.86	0.85
Participation in society	0.86	0.75

Table 4.30: Descriptive statistics for WHODAS domains by group

WHODAS domains	Control				Experimental			
	Start		End		Start		End	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Understanding and communicating	8.56	3.31	8.24	3.06	8.62	3.19	8.31	3.27
Getting around	9.26	4.39	8.60	3.24	8.56	3.58	8.85	3.34
Self-care	5.15	2.23	4.80	1.91	4.63	1.11	4.50	0.91
Getting along with people	6.38	2.21	6.48	2.43	6.37	1.82	6.04	1.31
Life activities (household)	9.00	1.41	9.00	1.41	14.00	2.91	11.04	3.08
Participation in society	11.78	5.07	10.72	3.05	11.33	2.91	11.04	3.08

Table 4.31: Analysis of covariance for WHODAS domains

Source	SS	df	MS	*F*	*p*	ε^2
Understanding and communicating						
Pre-measure (P)	11.62	1	11.62	261.16	0.00	0.85
Intervention (I)	0.01	1	0.01	0.16	0.69	-0.003
P x I	0.003	1	0.003	0.06	0.81	-0.003
Error	2.05	46	0.04			
Total	13.67	49				
Getting around						
Pre-measure (P)	9.02	1	9.02	36.50	0.00	0.41
Intervention (I)	0.59	1	0.59	2.39	0.13	0.02
P x I	0.82	1	0.82	3.33	0.08	0.03
Error	11.62	47	0.25			
Total	21.29	50				
Self-care						
Pre-measure (P)	3.03	1	3.03	81.02	0.00	0.44
Intervention (I)	0.01	1	0.01	0.24	0.62	-0.004
P x I	0.007	1	0.007	0.19	0.66	-0.004
Error	1.76	47	0.04			
Total	6.85	50				

Table 4.32: Two way ANOVA for WHODAS domains violated homogeneity of regression

Source	SS	df	MS	*F*	*p*	ε^2
Getting along with people						
Intervention (I)	0.67	1	0.67	7.74	0.01	0.08
Blocked pre-measure (B)	2.61	1	2.61	30.24	0.00	0.34
I x B	0.76	1	0.76	8.80	0.01	0.09
Error	4.05	47	0.09			
Total	7.51	50				
Life activities						
Intervention (I)	0.47	1	0.57	1.92	0.17	0.01
Blocked pre-measure (B)	12.73	1	12.73	51.66	0.00	0.49
I x B	0.66	1	0.66	2.66	0.11	0.02
Error	11.58	47	0.25			
Total	25.55	50				
Participation in society						
Intervention (I)	0.01	1	0.01	0.10	0.75	-0.01
Blocked pre-measure (B)	2.44	1	2.44	24.36	0.00	0.32
I x B	0.0001	1	0.0001	0.001	0.98	-0.01
Error	4.70	47	0.10			
Total	7.21	50				

Table 4.33: Pairwise comparisons with estimates of post-intervention scores and between-group differences for Getting along with people, life activities and participation in society

	Control Mean (SE)	Experimental Mean (SE)	Mean difference (SE) 95% CI (*p* value)
Getting along with people	1.62 (0.08)	1.31 (0.08)	-0.32 (0.11) [-0.54, -0.09] (0.008)
Life activities	1.68 (0.12)	1.90 (0.11)	0.22 (0.16) [-0.10, 0.54] (0.17)
Participation in society	1.47 (0.07)	1.43 (0.06)	-0.03 (0.10) [-0.23, 0.17] (0.75)

Table 4.34: Mixed anova or WHODAS domains

Source of variation		SS	df	MS	F	p	ε^2
Understanding and communicating	Time	0.03	1	0.03	1.49	0.23	0.0002
	Time x Intervention	0.01	1	0.07	0.31	0.58	-0.0003
	Error	1.08	48	0.02			
	Intervention	0.02	1	0.02	0.04	0.84	-0.01
	Error	26.68	48	0.56			
Getting around	Time	0.01	1	0.01	0.03	0.86	-0.003
	Time x Intervention	0.01	1	0.01	0.078	0.78	-0.003
	Error	8.74	49	0.18			
	Intervention	0.02	1	0.02	0.02	0.89	-0.01
	Error	39.70	49	0.81			
Self-care	Time	0.08	1	0.08	2.81	0.10	0.001
	Time x Intervention	0.02	1	0.02	0.62	0.43	-0.0002
	Error	1.32	49	0.03			
	Intervention	0.26	1	0.26	0.81	0.37	-0.001
	Error	15.52	49	0.32			
Getting along with people	Time	0.01	1	0.01	0.11	0.74	-0.001
	Time x Intervention	0.10	1	0.10	2.40	0.13	0.001
	Error	2.01	48	0.42			
	Intervention	0.04	1	0.04	0.13	0.73	-0.005
	Error	13.28	48	0.28			
Life activities (household)	Time	0.16	1	0.16	1.33	0.26	0.001

(Continued on next page)

Table 4.34 – continued from the previous page

Source of variation		SS	df	MS	*F*	*p*	ε^2
	Time x Intervention	0.02	1	0.02	0.20	0.65	-0.002
	Error	5.88	49	0.12			
	Intervention	0.24	1	024	0.22	0.64	-0.01
	Error	51.28	49	1.05			
Participation in society	Time	0.08	1	0.08	0.79	0.38	-0.0004
	Time x Intervention	0.01	1	0.01	0.13	0.72	-0.002
	Error	5.10	49	0.10			
	Intervention	0.01	1	0.01	0.02	0.88	-0.005
	Error	14.92	49	0.30			

Table 4.35: Differences in WHODAS domains between the start and end of the intervention determined by paired sample's t test (N = 54)

	Control				Experimental			
	t	df	p	Mean diff. (SE) 95% CI	t	df	p	Mean diff. (SE) 95% CI
Understanding and communicating	-0.59	24	0.56	-0.02 (0.03) [-0.09, 0.05]	-1.07	24	0.29	-0.05 (0.05) [-0.16, 0.05]
Getting around	-0.06	24	0.96	0.04 (0.08) [-0.14, 0.21]	0.46	25	0.65	0.04 (0.08) [-0.14, 0.21]
Self-care	-1.40	24	0.18	-0.08 (0.06) [-0.20, 0.04]	-0.90	25	0.38	-0.03 (0.03) [-0.09, 0.04]
Getting along with people	1.00	23	0.33	0.05 (0.05) [-0.05, 0.15]	-1.21	25	0.24	-0.08 (0.06) [-0.21, 0.05]
Life activities (household)	-1.03	24	0.32	-0.11 (0.11) [-0.33, 0.11]	-0.56	25	0.58	-0.05 (0.09) [-0.23, 0.13]
Participation in society	-0.65	24	0.52	-0.08 (0.12) [-0.33, 0.17]	-0.77	25	0.45	-0.03 (0.04) [-0.12, 0.06]

4.4.6 Balance measures

Table 4.36 presents the descriptive statistics of the balance measures. There was no effect of intervention type on balance, as determined by the ANCOVA with pre-intervention scores as covariate (see Tables 4.37 and 4.38 on pages 210-211). Balance measures during quiet bipedal standing from analysis of covariance with pre-intervention scores as covariate, adjusted post-intervention scores and between-group differences are shown at Table 4.39 on page 212.

Mixed ANOVA (see Tables 4.40 and 4.41 on pages 213-214) showed that with vision, there were significant reductions over time in ML SD, AP SD and the CoP excursion in the anterior-posterior direction, implying an improvement in balance in both groups of participants. During the eyes-closed state, only the CoP excursion in the medio-lateral direction, $F(1,46) = 4.97$, $p < .05$, $\varepsilon^2 = 0.08$) showed a significant change over time. However, no significant interaction effect was evident. There was not much between-group difference in the improvement in ML postural stability during the eyes-closed state. Paired samples' *t*-test results for balance measures with eyes open and eyes closed bipedal standing are presented at Tables 4.42 and 4.43 on pages 215–216.

Table 4.36: Balance measures descriptive statistics (during bipedal standing under two conditions: eyes open and eyes closed)

	Control				Experimental			
	Before		After		Before		After	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Eyes open								
AP SD (mm)	4.44	1.40	3.92	1.66	5.45	2.06	4.64	2.03
AP range (mm)	21.42	5.89	18.02	7.54	25.92	6.25	21.25	6.79
ML SD (mm)	2.13	0.83	1.84	0.59	3.15	1.89	2.56	1.52
ML range (mm)	12.42	4.46	10.17	3.78	17.82	10.24	13.97	7.72
CoP velocity ($mm.s^{-1}$)	29.47	6.72	31.48	10.43	32.69	10.73	32.38	9.58
Eyes closed								
AP SD (mm)	4.83	1.56	4.42	1.79	5.45	1.40	5.20	1.96
AP range (mm)	24.88	8.12	21.24	8.29	28.69	8.19	27.70	9.17
ML SD (mm)	2.27	1.31	1.95	0.83	2.62	1.45	2.32	0.78
ML range (mm)	14.45	9.27	10.86	4.02	15.06	7.76	12.92	4.38
CoP velocity ($mm.s^{-1}$)	30.69	8.27	30.83	10.40	37.32	9.91	33.89	10.16

Table 4.37: The analysis of covariance for CoP excursions in the anterior-posterior and medio-lateral directions with eyes open bipedal standing.

Source of variation	SS	df	MS	F	p	ε^2
AP SD(mm)						
Pre-measure (P)	20.56	1	20.56	8.43	0.006	0.11
Intervention (I)	5.73	1	5.73	2.35	0.13	0.02
P x I	7.45	1	7.45	3.06	0.09	0.03
Error	107.29	44	2.44			
Total	165.56	47				
ML SD (mm)						
Pre-measure (P)	10.74	1	10.74	17.77	0.00	0.14
Intervention (I)	0.35	1	0.35	0.57	0.45	-0.004
P x I	0.60	1	0.60	0.99	0.33	-0.0001
Error	26.61	44	0.61			
Total	69.21	47				
CoP velocity (mm.s^{-1})						
Pre-measure (P)	1290.90	1	1290.90	19.18	0.00	0.27
Intervention (I)	0.10	1	0.10	0.002	0.97	-0.01
P x I	1.56	1	1.56	0.02	0.88	-0.01
Error	2961.55	44	67.31			
Total	4602.51	47				
AP range (mm)						
Pre-measure (P)	48.92	1	48.92	1.07	0.31	0.002
Intervention (I)	1.57	1	1.57	0.03	0.85	-0.02
P x I	6.98	1	6.98	0.15	0.70	-0.02
Error	1961.03	43	45.61			
Total	2097.84	46				
ML range (mm)						
Pre-measure (P)	62.66	1	62.66	1.84	0.18	0.02
Intervention (I)	14.58	1	14.58	0.43	0.52	-0.01
P x I	1.50	1	1.50	0.04	0.84	-0.02
Error	1461.53	43	33.99			
Total	1686.46	46				

Table 4.38: Analysis of covariance for CoP excursions in the anterior-posterior and medio-lateral directions with eyes closed bipedal standing.

Source of variation	SS	df	MS	*F*	*p*	ε^2
AP SD (mm)						
Pre-measure (P)	25.22	1	25.22	8.66	0.005	0.13
Intervention	5.82	1	5.82	2.00	0.16	0.02
P x I	8.79	1	8.79	3.02	0.09	0.03
Error	131.04	45	2.91			
Total	173.35	48				
ML SD (mm)						
Pre-measure (P)	8.48	1	8.48	17.37	0.00	0.25
Intervention	0.35	1	0.35	0.71	0.41	-0.004
P x I	0.01	1	0.01	0.03	0.87	-0.01
Error	21.97	45	0.49			
Total	32.12	48				
CoP velocity (mm.s^{-1})						
Pre-measure (P)	798.01	1	798.01	9.14	0.004	0.14
Intervention	184.77	1	184.77	2.12	0.15	0.02
P x I	197.29	1	197.29	2.26	0.14	0.02
Error	3928.35	45	87.30			
Total	5076.59	48				
AP range (mm)						
Pre-measure (P)	663.37	1	663.37	9.20	0.004	0.14
Intervention (I)	0.02	1	0.02	0.00	0.99	-0.02
P x I	14.91	1	14.91	0.21	0.65	-0.01
Error	3243.42	45	72.08			
Total	4306.91	48				
ML range (mm)						
Pre-measure (P)	134.92	1	134.92	8.75	0.005	0.14
Intervention (I)	1.06	1	1.06	0.07	0.80	-0.02
P x I	25.63	1	25.63	1.66	0.20	0.01
Error	694.24	45	15.43			
Total	884.63	48				

Table 4.39: Balance measures with quiet bipedal standing from analysis of covariance with pre-intervention scores as covariate, adjusted post-intervention scores and between-group differences

	EYES OPEN			EYES CLOSED		
	Control Mean (SE)	Experimental Mean (SE)	Mean diff. (SE) 95% CI (*p* value)	Control Mean (SE)	Experimental Mean (SE)	Mean diff. (SE) 95% CI (*p* value)
AP SD (mm)	4.00 (0.35)	4.33 (0.32)	-0.32 (0.47) [-1.28, 0.63] (0.50)	4.47 (0.35)	4.99 (0.35)	-0.52 (0.50) [-1.52, 0.48] (0.30)
ML SD	2.06 (0.20)	2.24 (0.16)	-0.19 (0.26) [-0.71, 0.33] (0.47)	1.99 (0.14)	2.28 (0.14)	-0.29 (0.20) [-0.70, 0.11] (0.15)
CoP velocity (mm.s^{-1})	32.56 (1.76)	31.46 (1.66)	1.10 (2.42) [-3.77, 5.97] (0.65)	31.60 (2.04)	31.70 (1.99)	-0.11 (2.85) [-5.84, 5.63] (0.97)
AP range (mm)	19.05 (1.52)	20.75 (1.45)	-1.70 (2.10) [-5.94, 2.54] (0.42)	22.75 (1.77)	26.84 (1.73)	-4.10 (2.48) [-9.09, 0.90] (0.11)
ML range (mm)	11.53 (1.48)	13.47 (1.23)	-1.94 (1.92) [-5.82, 1.94] (0.32)	10.84 (0.80)	12.97 (0.79)	-2.13 (1.12) [-4.40, .13] (0.06)

Table 4.40: Mixed ANOVA results for balance measures with eyes open bipedal standing.

Source of variation		SS	df	MS	F	p	ε^2
AP SD	Time	12.82	1	12.82	8.29	0.006	0.09
(mm)	Time x Intervention	0.29	1	0.29	0.18	0.67	-0.01
	Error	71.13	46	1.55			
	Intervention	16.36	1	16.36	3.26	0.08	0.09
	Error	230.56	46	5.01			
ML SD	Time	3.97	1	3.97	8.37	0.006	0.05
(mm)	Time x Intervention	0.68	1	0.68	1.43	0.24	0.003
	Error	21.81	46	0.47			
	Intervention	18.66	1	18.66	6.04	0.02	0.21
	Error	142.12	46	3.09			
CoP velocity	Time	43.51	1	43.51	1.21	0.28	0.004
(mm.s^{-1})	Time x Intervention	23.21	1	23.21	6.45	0.43	-0.01
	Error	1654.71	46	35.97			
	Intervention	85.01	1	85.01	0.61	0.44	-0.03
	Error	6416.64	46	139.49			
AP range	Time	323.17	1	323.17	9.99	0.003	0.16
(mm)	Time x Intervention	19.81	1	19.81	0.61	0.44	-0.01
	Error	1487.53	46	32.34			
	Intervention	411.31	1	411.31	6.58	0.01	0.11
	Error	2875.58	46	62.51			
ML range	Time	159.25	1	159.25	4.08	0.05	0.06
(mm)	Time x Intervention	35.85	1	35.85	0.92	0.34	-0.002
	Error	1638.11	42	39.00			
	Intervention	583.02	1	583.02	8.17	0.007	0.20
	Error	2995.70	42	71.33			

Table 4.41: Mixed ANOVA results for balance measures with eyes closed bipedal standing.

Source of variation		SS	df	MS	F	p	ε^2
AP SD	Time	2.67	1	2.67	1.59	0.21	0.01
(mm)	Time x Intervention	0.51	1	0.51	0.30	0.59	-0.01
	Error	79.15	47	1.68			
	Intervention	9.85	1	9.85	2.64	0.11	0.05
	Error	175.27	47	3.73			
ML SD	Time	1.55	1	1.55	2.42	0.13	0.01
(mm)	Time x Intervention	0.10	1	0.10	0.16	0.69	-0.01
	Error	30.122	47	0.64			
	Intervention	2.25	1	2.25	1.28	0.27	0.01
	Error	83.08	47	1.77			
CoP velocity	Time	18.89	1	18.89	0.37	0.55	-0.01
(mm.s^{-1})	Time x Intervention	50.48	1	50.48	0.97	0.33	-0.001
	Error	2434.72	47	51.80			
	Intervention	495.40	1	495.40	4.10	0.05	0.15
	Error	5684.26	47	120.94			
AP range	Time	58.95	1	58.95	1.43	0.24	0.01
(mm)	Time x Intervention	53.24	1	53.24	1.29	0.26	0.003
	Error	1858.44	45	41.30			
	Intervention	524.26	1	524.26	6.29	0.02	0.17
	Error	3748.78	45	83.31			
ML range	Time	144.67	1	144.67	4.97	0.03	0.08
(mm)	Time x Intervention	30.87	1	30.87	1.06	0.31	0.004
	Error	1339.60	46	29.12			
	Intervention	19.14	1	19.14	0.35	0.56	-0.002
	Error	2510.16	46	54.57			

Table 4.42: Paired samples' *t*-test results for balance measures with eyes open bipedal standing

	Control (n = 27)				Experimental (n = 27)			
	Before Mean (SD)	After Mean (SD)	*t*(df) *p*	Mean diff. (SD) 95% CI	Before Mean (SD)	After Mean (SD)	*t*(df) *p*	Mean diff. (SD) 95% CI
AP SD (mm)	4.54	3.91	1.52 (22)	-0.62 (1.96)	5.48	4.64	2.71 (24)	-0.84 (1.55)
	(1.29)	(1.66)	0.14	[-1.47, 0.23]	(2.10)	(2.03)	0.01	[-1.48, -0.20]
ML SD (mm)	2.08	1.84	1.66 (22)	-0.24 (0.69)	3.13	2.56	2.45 (24)	-0.58 (1.17)
	(0.74)	(0.59)	0.11	[-0.54, 0.06]	(1.92)	(1.52)	0.02	[-1.06, -0.09]
CoP velocity ($mm.s^{-1}$)	29.15	31.48	-1.17 (22)	2.33 (9.52)	32.02	32.38	-0.25 (24)	0.37 (7.40)
	(6.39)	(10.43)	0.25	[-1.79, 6.45]	(10.37)	(9.58)	0.81	[-2.69, 3.42]
AP range (mm)	21.69	18.81	1.71 (22)	-2.88 (8.09)	25.83	21.25	2.75 (23)	-4.58 (8.15)
	(5.28)	(6.63)	0.10	[-6.38, 0.61]	(6.37)	(6.79)	0.01	[-8.02, -1.14]
ML range (mm)	12.19	10.82	1.55 (22)	-1.37 (4.21)	17.72	13.97	1.62 (23)	-3.75 (11.34)
	(4.17)	(3.01)	0.13	[-3.19, 0.46]	(10.45)	(7.72)	0.12	[-8.54, 1.04]

Table 4.43: Paired samples' t-test results for balance measures with eyes closed bipedal standing

	Control (n = 27)				Experimental (n = 27)			
	Before Mean (SD)	After Mean (SD)	t(df) p	Mean diff. (SD) 95% CI	Before Mean (SD)	After Mean (SD)	t(df) p	Mean diff. (SD) 95% CI
AP SD (mm)	4.89	4.42	1.13 (23)	-0.47 (2.06)	5.38	5.20	0.59 (24)	-0.19 (1.59)
	(1.37)	(1.79)	0.27	[-1.35, 0.40]	(1.38)	(1.96)	0.56	[-0.84, 0.47]
ML SD (mm)	2.27	1.95	1.38 (23)	-0.32 (1.12)	2.51	2.32	0.82 (23)	-0.18 (1.14)
	(1.29)	(0.83)	0.18	[-0.77, 0.16]	(1.36)	(0.78)	0.42	[-0.66, 0.28]
CoP velocity (mm.s^{-1})	30.27	30.83	-0.23 (23)	0.56 (11.85)	36.21	33.89	1.40 (24)	-2.31 (8.26)
	(8.09)	(10.40)	0.82	[-4.45, 5.56]	(8.29)	(10.16)	0.17	[-5.72, 1.10]
AP range (mm)	24.93	22.08	1.50 (23)	-2.85 (9.33)	27.78	27.70	0.05 (24)	-0.08 (8.55)
	(7.12)	(9.09)	0.15	[-6.79, 1.09]	(6.89)	(9.17)	0.96	[-3.61, 3.45]
ML range (mm)	14.57	10.86	2.04 (23)	-3.72 (8.92)	14.24	12.92	1.11 (24)	-1.32 (5.98)
	(9.18)	(4.02)	0.05	[-7.48, 0.05]	6.72	(4.38)	0.28	[-3.79, 1.14]

4.4.7 Perceived expended physical and mental effort, and heart rate

Descriptive statistics recorded at four time points (T1, T4, T8, T12) are shown at Table 4.44. The results show that heart rate for both groups was consistent at all time points although it was slightly higher in the experimental group. Previous studies have used heart rate variability as a indicator of exercise intensity (Zeni et al., 1996; Goodie et al., 2000; Cottin et al., 2004). However, there was no evidence of significant heart rate variability in the current study, thus any differences in exercise intensity could not be substantiated. This could be due to the light- and moderate- intensity nature of the physical exercises in both interventions, reflected by the perceived expended physical effort scores of the participants. Perceived expended physical effort for both groups throughout the intervention were in the 'fairly light' to 'very light' range on the Borg RPE (see Appendix C on page 281). For perceived mental effort, the scores were in the 'some effort' range on the SMEQ (see Appendix C.2 on page 283).

There was no effect of intervention type on perceived expended physical and mental effort, as determined by the ANCOVA with prevention scores as covariate (see Table 4.45), and on heart rate, as analysed using independent measures ANOVA by median split using pre-measures categorised into groups of high and low scores (see Table 4.46.) Results from the mixed ANOVA showed that no significant changes over time for heart rate (see Table 4.47). However, significant changes over time were found for perceived physical and mental effort where the control and experimental groups both had reduced post-intervention scores for perceived expended physical and mental effort. While the reduction in perceived physical effort in the control group slightly exceeded those of the experimental group, the reduction in perceived mental effort was larger in the experimental group.

Further testing of the means by paired sample *t* test again showed no differences in pre- and post-intervention heart rate. However, a significant reduction in perceived physical effort after the intervention was found in the control group $t(22) = -3.65$, $p = 0.001$, $d = -0.62$, and was near significance for the experimental group, $t(24) = -1.94$, $p = 0.06$, $d = 0.54$. For the experimental group, the reduction in perceived mental effort before and at the end of the intervention was significant, $t(24) = -3.37$, $p = 0.003$, $d = 0.90$ (see Table 4.48 on page 221).

Table 4.44: Descriptive statistics of expended physical and mental effort and heart rate at four time points (T1, T4, T8, T12)

	Control Mean (SD)	Experimental Mean (SD)
Physical effort		
T1	10.48 (1.85)	10.77 (1.65)
T4	10.59 (2.02)	11.33 (1.61)
T8	10.19 (1.76)	12.58 (7.36)
T12	9.41 (1.31)	9.81 (2.07)
Mental effort		
T1	39.47 (11.57)	55.93 (15.70)
T4	38.52 (10.11)	50.37 (10.84)
T8	35.97 (8.74)	44.75 (14.92)
T12	32.46 (9.95)	40.96 (16.28)
Heart rate		
T1	77.41 (5.69)	82.23 (11.00)
T4	77.07 (4.61)	84.14 (8.80)
T8	76.02 (4.35)	79.87 (9.28)
T12	77.67 (4.45)	81.80 (9.58)

Table 4.45: Analysis of covariance for perceived expended physical and mental effort

Source of variation	SS	df	MS	*F*	*p*	ε^2
Perceived expended physical effort						
Pre-measure (P)	13.43	1	13.43	4.92	0.03	0.07
Intervention (I)	6.23	1	6.23	2.28	0.14	0.02
P x I	5.62	1	5.62	2.06	0.16	0.02
Error	120.13	44	2.73			
Total	142.89	47				
Perceived expended mental effort						
Pre-measure (P)	207.49	1	207.49	1.10	0.30	0.002
Intervention (I)	55.10	1	55.10	0.29	0.59	-0.01
P x I	3.94	1	3.94	0.02	0.89	-0.02
Error	8318.62	44	189.06			
Total	9404.30	47				

Table 4.46: Two way ANOVA for heart rate

Source	SS	df	MS	*F*	*p*	ε^2
Heart rate						
Intervention (I)	100.18	1	100.18	2.27	0.14	0.02
Blocked pre-measure (P)	469.48	1	469.48	10.62	0.002	0.15
I x B	90.51	1	90.51	2.05	0.16	0.02
Error	1945.68	44	44.22			
Total	2841.10	47				

Table 4.47: Mixed analysis of variance for perceived expended physical and mental effort, and heart rate

Source of variation		SS	df	MS	*F*	*p*	ε^2
Perceived physical effort	Time	23.64	1	23.64	11.24	0.002	0.07
	Intervention x time	0.001	1	0.001	0.001	0.98	-0.007
	Error	96.72	46	2.10			
	Intervention	3.85	1	3.85	0.93	0.34	-0.001
	Error	191.06	46	4.15			
Perceived mental effort	Time	2404.73	1	2404.73	15.12	0.00	0.09
	Intervention x time	426.95	1	426.95	2.69	0.11	0.01
	Error	7315.47	46	159.03			
	Intervention	3875.01	1	3875.01	17.67	0.00	0.15
	Error	10089.64	46	219.34			
Heart rate	Time	1.27	1	1.27	0.09	0.77	-0.002
	Intervention x time	10.13	1	10.13	0.70	0.41	-0.001
	Error	662.12	46	14.39			
	Intervention	548.21	1	548.21	4.57	0.04	0.06
	Error	5522.26	46	120.05			

Table 4.48: Differences in perceived expended physical and mental effort, and heart rate determined by paired sample's *t* test (N = 54)

	Control				Experimental			
	t(df)	d	*p*	Mean diff. (SE) 95% CI	*t*(df)	*d*	*p*	Mean diff. (SE) 95% CI
Physical effort	-3.65(22)	-0.62	0.001	-1.00 (0.27) [-1.57, -0.43]	-1.94(24)	0.54	0.06	-0.99 (0.51) [-2.03, 0.06]
Mental effort	2.09(22)	-0.56	0.05	-5.80 (2.87) [-11.56, -0.03]	-3.37(24)	0.90	0.003	-14.24 (4.23) [-22.96, -5.51]
Heart rate	0.36 (22)	0.09	0.72	0.42 (1.16) [-1.98, 2.82]	-0.85(24)	0.09	0.40	-0.88 (1.04) [-3.02, 1.26]

4.5 Discussion and conclusion

This chapter will discuss the findings from older adults with self-reported chronic musculoskeletal pain within the context of technology acceptance, exergaming experience, pain, function and balance.

4.5.1 Exergaming acceptance in older people with chronic pain

All measured technology acceptance variables increased significantly over the period of the intervention, suggesting that participants had responded favourably to the exergaming intervention, in agreement with the previous study that comprised findings from healthy older people. The highest increase was observed in performance expectancy, which indicated that participants perceived that exergaming was an effective way for them to exercise. An underlying explanation could be associated with the learning and mastery of exergaming skills over time (Shoemaker, 2003). Most participant's exergaming skills improved with repetitive practice throughout the intervention, leading to an awareness of having physically moved, exercised and possibly feeling fitter. If the exergaming technology was able to facilitate feelings of bodily movement, energy expenditure or even exercise-induced feelings such as enjoyment, exhilaration, physical exhaustion similar to those of a standard exercise routine, exergaming was likely to be perceived as useful.

Similarly, the significant increase in facilitation conditions and self-efficacy demonstrate that the participants' exergaming competency increased due to repetitive practice throughout the intervention. In this case, participants rated their facilitation conditions based on their personal perceptions of their exergaming performance. It could be that frequent practice of exergaming fostered self-confidence amongst the participants (Feltz, 1988), which in turn, also nurtured a sense of personal self-efficacy (Bandura, 1982). If participants felt confident that they would be able to meet the physical and mental requirements of exergaming, facilitation conditions for exergaming would improve.

Effort expectancy within the context of the current study was associated with how easy the participants would find exergaming to be. Not surprisingly, higher scores in effort expectancy was found in the control group which performed standard exercises. Unlike the exergaming group, performing the physical movements did not involve interaction with an external source. The standard exercise routine comprised planned and structured repetitive physical movements (Caspersen et al., 1985) which meant that the participants were exercising *with* themselves instead of having to engage in additional visual or auditory stimuli. This could have made the exercising process easier.

Social influence is an integral factor in encouraging participation in physical activity among the elderly (Courneya and McAuley, 1995; McAuley et al., 2003). Older people with higher social support were more likely to be physically active compared to those who were more socially isolated or less socially integrated (Courneya and Hellsten, 1998; Eyler et al., 1999). In the current study, social influence represented the social environment that would influence the behaviour of the participants. This included support from or social interaction with spouses, family and friends. Some people take part in physical activity because they look forward to the mere social contact that occurs during exercise programmes (Gillett, 1988). The significant social increase found in the current study accords with the findings of other studies (House et al., 1988; Carron et al., 1996; Eyler et al., 1999).

The current study found increases in behavioural intention to use exergaming. Taken together, it seems that the other technology acceptance variables significantly contributed to the increase in behavioural intention to exercise. This was also observed in the control group. Several factors could have influenced this increase. Firstly, the affective state of a user plays an important role in his acceptability of a new activity or technology (Billis et al., 2011). Feelings of enjoyment and positive engagement would definitely endorse intentions of wanting to continue exercising in the exergaming environment (Davis et al., 1992). Secondly, if older people found the exergames to be both useful and easy to follow, they were more likely to express intention to continue using the exergaming technology (Muuraiskangas et al., 2010). Thirdly, verbal or non-verbal social behaviour nurtures change in any particular behaviour (Zajonc, 1965; Brodsky, 1967). This would include encouragement, feedback or supervision and even the mere presence of the author during the sessions (Markus, 1978). Studies have shown that exercise capacity increases with levels of encouragement from physical trainers (Guyatt et al., 1984; McNair et al., 1996). Levels of self-confidence also affect sports performance (Feltz, 1988). Performing standard exercises with adequate feedback or supervision under controlled conditions seems to encourage exercise behaviour and increase physical activity (Opdenacker et al., 2008). Therefore, these factors are probable explanations for the increase in behavioural intention to exercise in the control group.

The modified Technology Acceptance model was employed at five time points (i.e. T0, T1, T4, T8 and T12) throughout the intervention to see how older people's behavioural intention would be influenced by the other technology acceptance variables. No significant effects of intervention, age and gender on behavioural intention were found. There were only two small but significant effects of social influence on behavioural intention (i.e. at T1 and T4). Furthermore, the influence of interaction effects on older people's behavioural intention was found to be minimal and inconsistent. These results were not sufficient for the current study to reach a conclusive explanation for these effects.

More important, the modified UTAUT model showed a pattern of influence of the technology acceptance variables on behavioural intention. In the initial stages of the intervention, effort expectancy significantly influenced behavioural intention to use exergaming. This influence was then taken over by performance expectancy midway through and towards the end of the intervention. At the final time of testing, both performance expectancy and effort expectancy significantly influenced older people's behavioural intention to use exergaming. This is an interesting finding because it has not been previously described in the literature.

Instead of performance expectancy, the current study found that it was effort expectancy that had more influence on behavioural intention in the early stages of exergaming as previously found by Davis et al. (1989), but differed from Venkatesh et al. (2003) because performance expectancy did not emerge as the strongest predictor of behavioural intention. According to Venkatesh et al., (2003), performance expectancy is the strongest predictor of behavioural intention and remains significant at all points of measurement in both voluntary and mandatory settings. This finding of the current study suggests that in the beginning, older people placed more importance in their physical ability to exercise with the exergames, that is, they tried exergaming to see if they could *do* it, and eventually, if they could, was it *useful* enough to continue? This was then reflected in the influence of performance expectancy in determining behavioural intention starting midway through the intervention.

The influence of previous behaviour in predicting future behaviour is well known, and has also been observed in other studies (Lechner et al., 1997; Ferguson and Bibby, 2002). The current study adapted the modified UTAUT model from Davis and Venkatesh (2004) to assess the longitudinal effects of the acceptance variables on older people's behavioural intention to use the exergaming technology. The second modified UTAUT model used previous behavioural intention as a representative of previous usage of the exergaming technology to predict behavioural intention in the next stage. Davis and Venkatesh (2004) found that if people perceived that using a particular technology was useful and acceptable to them at an early stage, they were more likely to form intentions to use that technology at a later time. This also applied in mandatory situations, for example, if the technology had been implemented in a work place. According to Davis and Venkatesh (2004), constructs of intention and perceived usefulness could significantly predict future intention to use and usage behaviour. Moreover, their findings revealed a striking observation – that whenever these predictors of intention were significant, the influence of other acceptance variables over behavioural intention ceased and became non-significant, reinforcing the importance of early users' perceptions.

Results from the second modified UTAUT model showed firstly, that previous behavioural intention significantly predicted future behavioural intention to use exergaming at all times of testing. At T1, T4 and T12, when previous behavioural intention remained a significant predictor of the subsequent intention, there were no significant effects on subsequent intention from the other main acceptance variables (i.e. effort expectancy, social influence, intervention, age and gender). However, there was an exception of testing found at T8, where behavioural intention was also significantly influenced by effort expectancy. Nevertheless, when interaction effects were included in the model, effort expectancy ceased to have any effect on behavioural intention. These findings are consistent with Davis and Venkatesh (2004). They seem to suggest that once older people expressed intention to use exergaming, they would do so in future, and when the decision *intending* to use is made, there is less priority on other factors such as usability or social opinions because they have already intended to continue with it.

4.5.2 The exergaming experience of older people with chronic pain

Participants in the experimental group responded positively to the exergaming sessions, finding the exercise experience to be pleasant, challenging and mentally stimulating, thus implying having experienced flow. Similar findings have been reported in other studies (Jung et al., 2009, Graves et al., 2010). Significant increases over time were found in all of the nine dimensions of flow state experienced by older people with chronic pain. The levels of flow state also significantly increased. This was evident in both groups, supporting the notion of the flow phenomenon in sport (Jackson and Roberts, 1992; Young and Pain, 1999). This also reflected the occurrence of flow in an older age group of people (Payne et al., 2011), and that flow can be experienced across all ages (Nakamura and Csikszentmihalyi, 2002).

The present findings seem to be consistent with other exergaming research which reported high enjoyment in users (Williams, Soiza, Jenkinson and Stewart, 2010; Wollersheim et al., 2010; Hale et al., 2012). The evidence in the current study is speculative that older people's flow experience as a result of exergaming is correlated with positive affect and engagement (Karageorghis et al., 2000). In addition, the findings of the current study as reflected in the participants' enjoyment and involvement in exergaming suggest that exergaming facilitates and offers conditions conducive to flow (Thin et al., 2011).

The current study found an effect of intervention on the concentration aspect of flow state, where there were statistically significant increases of concentration in both the control and experimental groups (i.e. standard exercise and exergaming). No pairwise differences were found between the adjusted means after the intervention. There were also significant differences in perceived mental effort at the start and end of the intervention where the reduction in perceived mental effort was larger in the experimental group. This shows that although participants' concentration increased significantly during both forms of exercise, there was a significant decrease in perceived mental effort. In short, although participants in both groups had to concentrate more to do the exercise activity, perceived invested mental effort was less in the experimental group (i.e. it became easier).

For both groups, a probable reason for the increase of concentration is that over time the participants had familiarised themselves to the laboratory environment, thus inducing related behaviours[4] (Bouts and Avermaet, 1992). In the current study, participants became more engaged in the intervention over time. People feel more comfortable and tend to increase their social and functional abilities when they are in familiar environments (Kaplan and Kaplan, 1982; Bouts and Avermaet, 1992). At the beginning of the intervention, some participants had expressed themselves feeling a bit shy or slightly apprehensive. Upon overcoming this shyness and becoming more familiar being in a laboratory environment, most participants eventually became used to exercising in the designated area, and thus, were able to focus their attention more on what they were doing.

For the experimental group, the increase of concentration may be due to the gaming nature of the exergames, which require the participants to focus on what's going on in the video game in order to interact with it. With practice, the effort of concentration became easier as indicated by the significant reductions in perceived mental effort. The similar increase in concentration among control group participants most likely points to their involvement in taking part in the current study. According to Zajonc (1965), the presence of another individual is sufficient to produce effects in the behaviour of others. This "individual" need not engage in another other behaviour to influence people.

[4] e.g. being familiar with the laboratory location, testing procedures or knowing what to expect and anticipating how to react in the testing session.

Their mere presence is enough (Markus, 1978). At all times, all participants in the current study exercised under supervision of the researcher. This was to provide exercise instruction and ensure safety. While the experimental group had the exergames to interact with, the control group did their exercises in attendance of the researcher. If they knew they were being watched, it is likely that they could have made an unconscious effort to concentrate more and conform to the exercise routine that was required of them. Nevertheless, the current findings support the relevance of exergaming in encouraging mental concentration in older people (Gao and Mandryk, 2012), confirming the cognitive advantages of exergaming (Staiano and Calvert, 2011*a*; Anderson-Hanley et al., 2012).

4.5.3 Does exergaming have any effect on older people's postural sway in comparison to a standardised exercise protocol?

The current study evaluated the effects of exergaming on older people's balance in comparison to those of standard exercise where balance was measured with a Kistler™ force platform as the range and standard deviation of the centre of pressure (CoP) excursions in the anterior-posterior and medio-lateral directions, as well as the CoP velocity during quiet bipedal standing. The conditions for this were two-legged stance with eyes open and eyes closed.

The significant improvement over time in postural sway parameters in both groups suggests that short-term exercise contributed to improved balance in the sample, consistent with previous intervention studies (Malmros et al., 1998; Wolf et al., 2001; Kuukkanen, 2000; Rogers et al., 2001; Kaesler et al., 2007; Tamari, 2010; Williams, Brand, Hill, Hunt and Moran, 2010). Favourable outcomes in older people's balance have also been reported in exergaming intervention studies (Williams, Soiza, Jenkinson and Stewart, 2010; Agmon et al., 2011; Bateni, 2012).

The current study was not able to find conclusive evidence of intervention effects on older people's balance during quiet bipedal standing with eyes open and closed. Significant reductions over time were observed on postural sway parameters (ML SD, AP SD and the CoP excursion in the anterior-posterior direction) when participants from both groups stood quietly with eyes open. With eyes closed, although there were significant reductions over time observed in the CoP exercusion in the medio-lateral direction for both groups, there was not much difference in these reductions between the two groups. Nevertheless, the findings show speculative evidence of at least some balance improvement after participating in either exergaming or standard exercise for six weeks.

4.5.4 Does exergaming have any effect in older people's self-reported health status, chronic pain and physiological response?

Regarding health status, all of the WHODAS domain scales obtained from participants were scored much lower when compared to other patient populations (i.e. patients with schizophrenia (McKibbin et al., 2004; Garin et al., 2010) and stroke (Schlote et al., 2009). This indicated low functional disability in the participants of the current study. Furthermore, the lowest scores were obtained in the Self-care domain (e.g. washing, bathing and dressing up), reflecting a high level of independence in personal care among participants in the current study. This collectively indicated that most of the participants had low physical disability and were still able to carry out everyday household and social activities despite having chronic pain. Although results showed an opposite direction of interaction for getting along with people, the reduction in post-intervention scores in the experimental group suggested that psychosocial effects of exergaming (Wollersheim et al., 2010) were socially beneficial for older people. This is suggestive of some improvement in older people's social activities where they either socialised more (e.g. made new friends), interacted more with their friends and families, or adopted a more positive outlook.

Although no significant differences were found in most of the self-reported pain variables at the start and the end of the study, there is tentative evidence suggesting that exergaming may have had some effect on the pain experience (see Appendix H at page 356). In the study, all participants were required to perform physical movements whilst standing up. The reduction of reported occurrence of foot pain upon completion of the study significantly differed by intervention. The experimental group reported having less foot pain at the end of the study (see Appendix H on page 357). Furthermore, the improvement of pain intensity in the experimental group suggested that exergaming may have alleviated the experience of pain to some extent (Magora et al., 2006). During exergaming, users become involved or gradually engaged with colourful virtual reality imagery which requires them to think about their movements to interact with the exergame. Focusing on the exergame may have kept the participants' attention away from thinking about themselves, or the difficulties in their lives, which could be related to having chronic pain. Hence, exergaming provides a form of distraction so that attention is moved away from pain (Magora et al., 2006; Rutter et al., 2009) and consequently leads to some relief from the experienced physical pain (Rizzo, 2006).

There was no evidence of significant heart rate variability. A possible explanation is that the nature of exercises for both interventions required were not vigorous or strenuous, and were performed according to the participants' own pace taking rests whenever they wished to. However, results indicated that exergaming sessions became easier for participants where there was a reduction in perceived expended physical and mental effort. This could be due to repetition and practice, but together with the statistically significant increases in flow experience, this suggests that older people reacted positively with the exergaming intervention. In short, they enjoyed their exergaming sessions which became easier over time.

4.6 Conclusion and limitations

The current study showed that the exergaming technology was likely to be favourably received by older people with chronic musculoskeletal pain. There was evidence of older people's enjoyment of the exergaming experience, thus facilitating the experience of flow. The flow experience from exergaming should be able to encourage older people to persist at and continue to partake in more exergaming because of the experiential benefits it promises (Csikszentmihalyi, 1990). The indication of improved postural sway due to significant medio-lateral reductions found in the experimental group suggested that older people with chronic pain could benefit from at least, subtle improvements in balance after exergaming. Because exergaming was also associated with an improvement in positive affect and sense of well-being at 6 weeks, older people with chronic pain should be encouraged to continue exercising in the exergaming environment in the long run.

Strengths in the current study were its pre-post study design and the longitudinal collection of data. It was the first to investigate exergaming acceptance in a population of older people with chronic pain, and describe changes in their perceived pain intensity, flow experience, health status and balance over six weeks. A limitation of the study was that the sample was small in size, and comprised older people who were indicative of low functional disability, in spite of having chronic pain, otherwise described as a preclinical population of older people with chronic pain. Future studies are required to explore the effects of exergaming in a population of older people who are more adversely affected by chronic pain, such as those in later stages of arthritic diseases.

Chapter 5

General discussion and conclusions

5.1 Introduction

Before carrying out the studies investigating exergaming in older people, the author of the current thesis found evidence in the current literature to suggest the potential for exergaming to be a sustainable physical activity for older people (Wollersheim et al., 2010; Anderson-Hanley et al., 2012). Among the benefits from exergaming were enhanced feelings of well-being (Wollersheim et al., 2010), increased social interaction (Williams, Soiza, Jenkinson and Stewart, 2010) and enjoyment (Graves et al., 2010). However, there was a significant lack of evidence in the literature relating to how older people perceived and experienced exergaming, and whether they would intend to use this technology. Few studies have looked into technology acceptance of exergaming among older people. This topic of acceptance is important because benefits from exergaming may only be derived if the technology is used.

Whether a technology is accepted or not, actually occurs before it is used (Davis, 1989) whereby, the exergaming technology will not serve any purpose if older people, for any reason, do not accept the available technology. Davis et al. (1989) posits that when users are presented with a new technology, a number of factors such as performance expectancy and social influence, influence their decision about how and when they will use it. Hence, acceptance of a technology is important because it determines the future use of the technology. Therefore, the current thesis investigated older people's acceptance of exergaming by using a modified version of the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003).

The author of the current thesis also found very little reported about older people's experience of flow. Studies that have investigated flow in older people have not looked into the occurrence of flow in exergaming. Flow is an important topic of investigation because of its underlying role in how people are motivated whilst being in a state of flow, which contributes to something further from the engaged activity (Csikszentmihalyi, 1990). In the exercise context, this implies that people who experience flow during the exercise activity would likely feel intrinsically rewarded and encouraged to persist in performing the exercise activity. Within the current thesis, the investigation of flow in older people during exergaming provided insights into older people's flow experience associated with exergaming, as an example, the differences in perceived flow levels between the start and end of the intervention.

In reviewing the literature on balance in older people, studies that have investigated balance, particularly postural sway in older people have tended to employ physical-exercise interventions (Lord et al., 1995). Only two studies report the potential of exergaming to significantly improve postural stability in older people (Kim et al., 2009;

Agmon et al., 2011). The sample population in those studies were older people with chronic hemiparetic stroke (Kim et al., 2009) and impaired balance (Agmon et al., 2011). Furthermore, although previous exergaming studies have investigated aspects of physical and psychosocial well-being in older people (Wollersheim et al., 2010), none has yet examined exergaming effects in a population of older people with chronic pain.

To fill this knowledge gap, the current thesis further investigated the effect of exergaming on older people's self-reported health status, physiological response and balance in older people with chronic pain, a clinical population known to have balance impairments and at high risk of falling. By investigating the effect of exergaming on postural sway over three different time intervals: the first 10, latter 20 and overall 30 seconds of quiet standing, this research was able to determine if exergaming enhanced balance during or following restabilisation of the body, after standing up from a seated position, compared to that of standard exercise.

This chapter evaluates the overall findings for older people's acceptance and experience of exergaming and the effect of exergaming on postural sway during quiet standing in older people with chronic pain. Differences in the effects of exercise modality (exergaming or standard exercise) in older adults are discussed. Methodological strengths and limitations of the current study are also discussed. Recommendations are made for future research.

5.2 Aims of the current thesis

This thesis was concerned with investigating how older people perceived and experienced exergaming, and whether this technology was acceptable to them. The current thesis began by investigating the acceptance of the exergaming technology in a population of healthy older people. The first study involved healthy older people (22 female 6 male; age range 50–85 years; mean 65 years, SD 8) who attended twice weekly 40-minute exergaming sessions for three weeks. Results showed evidence of older people's acceptance of exergaming. Measured acceptance variables did increase significantly over time. There was also no indication of any decrease in the quality of their perceived exergaming experience. Following on from the success of the first study, the investigation of exergaming technology acceptance was then extended to older people with chronic musculoskeletal pain (42 female 12 male; age range 65–86 years, mean 71 years, SD 5), who participated in either exergaming or standardised physical exercise sessions twice weekly 40-minute exercise sessions for six weeks. The current thesis also investigated flow experience in older people while exergaming by using the Flow State Scale (Jackson and Marsh, 1996). For both studies, flow was measured at the end of every exercise session. Perceived expended physical exertion and subjective mental effort were recorded at every session. Balance measures were recorded at baseline and the end of the second study.

Therefore, this thesis provides novel evidence, addressing a number of important gaps in current literature including:

1. The acceptance and experience of exergaming in older people.

2. Flow state during exergaming in older people.

3. The additive effects of exergaming to improve emotional well-being and enhance balance in older people with chronic pain.

5.3 Original contributions to scientific knowledge

The results of this thesis have implications for theoretical accounts of technology acceptance, exercise experience, chronic pain and balance in older people.

5.3.1 Technology acceptance

The acceptance of exergaming in the context of new technology for older people was supported by the results in this thesis. In both studies[1], participants reported their experience of exergaming to be positive. For the first study, older people's scores for behavioural intention to use exergaming significantly increased from the start to the end of the intervention, indicating a likelihood of older people's acceptance of the technology. The other technology acceptance variables increased significantly although there were slight fluctuations in scores between exergaming sessions. When the participants were asked to give their opinions on the exergaming sessions, enjoyment

[1] The first involved healthy older people, and the second involved those with chronic pain.

was most frequently mentioned. Participants' responses from the open-ended evaluations suggested that enjoyment was important in prolonging exergaming participation. Significant increases in older people's behavioural intention to use exergaming were also demonstrated in the second study that involved a population of older people with chronic pain. The significant increases in the other technology acceptance variables was found to be similar to those of the first study, where some acceptance scores fluctuated at different time points during the intervention.

The current thesis is the first of its kind, outside the Information Systems research area to use the UTAUT (Venkatesh et al., 2003) to analyse older people's behavioural intention to use exergaming. The modified version of the UTAUT was used to investigate the influence of three acceptance variables (i.e. performance expectancy, effort expectancy and social influence), age and gender on older people's behavioural intention to use the exergaming technology. For healthy older people, multiple regression analyses showed that performance expectancy was the strongest predictor of behavioural intention to use exergaming. In this population, previous behavioural intention also influenced their future intention to use the exergaming technology at all time points of the study. In addition, findings from the multiple regressions analyses at the third time-point (T3) support the findings of Davis and Venkatesh (2004) which state that when future behavioural intention is significantly predicted by the previous behavioural intention, other variables in the model do not account for any additional variance in the outcome.

While performance expectancy was the strongest determinator of behavioural intention to use exergaming, results from the second study revealed a different pattern of influence when testing was done over a longer period. Here, effort expectancy emerged as the strongest predictor of older people's behavioural intention to use exergaming, followed by performance expectancy. An interesting pattern of influence was found where effort expectancy significantly influenced behavioural intention in the early stages of the intervention (i.e. at baseline, T0 and the first time-point, T1) and then this role was taken over by performance expectancy in the later stages (i.e. at T4, T8 and T12). This indicates that in order for exergaming to be perceived as an effective exercise, older people first need to see if they are capable of using the exergaming system, which ideally would improve with practice, and then once they had experienced self-efficacy in exergaming, attention was shifted towards the usefulness of the technology.

The results from both studies show firstly, that older people are very likely to use exergaming in the future, if it were readily made available. While performance expectancy was the strongest determinator of behavioural intention to use exergaming, results from the second study revealed a different pattern of influence when testing was done over a longer period. These results also show that exercising in an exergaming environment can yield positive user-perceptions after six weeks of direct exergaming experience. Furthermore, this evidence confirms the findings of Davis and Venkatesh (2004), that previous behavioural intention significantly predicted future behavioural intention to use exergaming. This clearly demonstrates the importance of formative experience which influences how older people make decisions and choices.

5.3.2 Flow

The occurrence of flow in an exergaming activity among older people was supported by the results in this thesis. The Flow State Scale (Jackson and Marsh, 1996) was used to measure older people's flow experience while exergaming. Results from the first study showed that there were significant increases over time in most of the flow dimensions, indicating that there was no deterioration in the quality of the exergaming experience. This shows that older people found the exergaming experience to be overall, positive and enjoyable.

Results from the second study add further support to the occurrence of flow, as demonstrated by the significant increases over time in all of the flow variables and levels. A notable finding from the second study was the significant influence of exergaming on older people's concentration, as found from the results of the ANCOVA. This indicated the the potential of exergaming, when performed safely and purposefully, to facilitate concentration in older people. This implies that consequently, exergaming could improve cognitive functioning in older people in areas such as memory retention and response.

Over time, the largest effect size was found in unambiguous feedback in both groups. An important finding from this is that older people are able to receive clear feedback from exergaming, regarding how they were performing in relation to goal accomplishment for a particular exergame. This means that a physical activity becomes purposeful when older people receive immediate and clear feedback from the exergaming technology. This then allows them to make adjustments that are required to make sure that they are able to keep up the challenge, or in short, play the exergame properly. For the control group, this finding might be interpreted as such – the results indicated that it was possible for older people to gain self-perceived feedback on the physical exercises that they performed, as the participants became familiar with the exercise protocol with repetition over time, so they instinctively knew how they were coping with the exercises over time.

Interestingly, levels of flow in both the exergaming and control groups significantly increased from the start to the end of the intervention. This suggests that older people's exercise skills increased with practice over time, along with increased levels of flow. This is comparable to the findings of Payne et al. (2011). They investigated older people's levels of flow in relation to an activity of their choice, including the level of skill and cognitive demands[2] that were required for that particular activity. Although Payne et al. (2011) did not focus on exercise, their findings showed that older people who had higher fluid ability[3] achieved higher states of flow when they were doing activities that were cognitively demanding, which matched their level of skill. In the current thesis, this is demonstrated in the significant increases over time in flow variables such as autotelic experience and challenge-skill-balance.

The current thesis has shown that being older does not diminish the capacity to experience flow state (Payne et al., 2011) . In fact, flow may be an important factor to consider in understanding how older people may use exergaming to their benefit. In addition,

[2]Examples of activities that were cognitively demanding are working, reading and literacy activities, and completing puzzles and challenging games such as crosswords, cards and Sudoku. Examples of less cognitively demanding activities are watching television and attending parties.

[3]Refers to the level of skill or ability that a person has for interacting and performing a particular activity (Carroll, 1993).

this thesis provides evidence that flow is attainable not only by highly accomplished athletes (Jackson, 1992) and artists (Martin and Cutler, 2002) but also this cohort of older people who did not have highly skilled athletic abilities or previous exergaming experience. These results reinforce Nakamura and Csikszentmihalyi's (2002) assertion that flow can happen in almost any activity and shows evidence that it is the subjective challenges and subjective skills required and expanded in exergaming, that influence the quality of the exergaming experience.

5.3.3 Chronic pain, self-reported health status and physiological response

Results from the second study showed firstly, that the overall self-reported pain intensity was significantly reduced in the exergaming group, as determined by a paired-samples *t*-test. This suggests that older people with chronic pain perceived having felt some improvement in pain intensity after participating in a six-week exergaming intervention.

Secondly, measurements of pain dimensions (somatosensory, emotional and well-being) by administering the Multi Affect and Pain Survey (MAPS) questionnaire (Clark et al., 2002) to participants at the start and end of the intervention have generated a few novel findings. Although improvements in pain were less obvious in the MAPS scores, there were at best, some tentative indications of benefit after the intervention in both the control and exergaming groups. This was demonstrated in the statistically significant improved reduction in older people's perceived experience of thermal pain, depressed mood and affiliative feelings, indicating that regardless of type, exercise activities have a potential role in alleviating chronic pain to some extent. The significant change in depressed mood and affiliative feelings was larger in the exergaming group. The reduction in expressions of anger (i.e. feelings of anger, outrage, upset and annoyance) over time was also greater in the exergaming group although the decrease approached significance. These results collectively imply that some aspects of older people's sensory-related and emotional pain may improve after exergaming.

Thirdly, results showed a significant improvement in social interaction in the exergaming intervention, where scores significantly reduced, indicating less difficulty in older people's involvement in community, social and civic life after the exergaming intervention. This suggests that there was a more sociable outlook in older people who had participated in exergaming sessions.

Lastly, results indicated that older people with chronic pain, after having participated in exergaming sessions, perceived exergaming to be a light-intensity exercise that became easier to do over time, as demonstrated in the near significant reduction in perceived mental effort in the exergaming group. This indicates that the older population is capable of using the exergaming technology for exercise. This also suggests that exergaming may a suitable alternative form of exercise for older people if gaming levels can be adjusted according to the user's choice, following recommendations from the American Geriatric Society Clinical Practice Guidelines on the management of chronic pain in older people (AGS, 2001) that specific exercises should be selected on the basis of joint stability and degree of pain in older people with chronic musculoskeletal pain. In addition, there was no evidence of self-reported muscle fatigue among participants who participated in exergaming, supporting AGS recommendations that muscles should not be exercised to fatigue.

5.3.4 Balance

The many health benefits in relation to postural stability associated with exercise are well known. Similarly, in the context of exergaming and balance, results from this thesis are supportive of the balance-enhancing effects of exergaming. Participants demonstrated significant improvements in balance over time with eyes open (i.e. reductions in ML SD, AP SD and the CoP excursion in the anterior-posterior direction) after a 6-week period of either exergaming or standard exercise. Exergaming may have had a greater effect on postural sway when visual sensory information is removed, as found in the experimental group that demonstrated a statistically significantly lower reduction of CoP excursion in the medio-lateral direction, than in the control group.

5.4 Study strengths

This thesis presents two robustly designed studies, using scientific methods that provide novel, clinically important findings which will inform future research. The first phase of this PhD, investigated healthy older people's experience of exergaming, and whether the technology was acceptable to them. The findings have been presented at an international conference, following peer-review selection (see Appendix I on page 358). The second phase was an extension of the investigation to older people with chronic pain, which included further investigation into the effects of exergaming on self-reported health status and function, chronic pain, physiological response and balance.

In the current thesis, the first study which was of a longitudinal repeated-measures cohort design was an efficient way to investigate older people's acceptance and experience of exergaming using the sample size of n = 28 (healthy older adults who exercised regularly). The second study used an experimental design using the sample size of n = 54 from a clinical population of older adults with chronic pain randomised into two groups (exergaming and standard exercise), tested at four time points (T1, T4, T8 ad T12) throughout the intervention.

A strength of this thesis is that it provides evidence of older exercisers' likely acceptance of exergaming. It has portrayed the intrinsic effect of virtual reality on exercise. It shows that older people will continue with an exercise programme if they find it beneficial and when ideally, given adequate supervision and technical support. This research also shows a promising future for further development of exergaming interventions for older people.

The current research has documented health status, pain prevalence and intensity in a sample of older people with chronic musculoskeletal pain, which would be of further use to other researchers in a wide range of settings who wish to document health status and pain in older people. Although no significant differences were found in most of the self-reported bodily locations of pain, there was some improvement in the overall post-intervention pain intensity in the experimental group. In addition, there was some evidence of improved emotional well-being after the intervention. Through exergaming, older people may be motivated to take charge of their lives and to be active, and generate better adherence to exercise, ideally, leading to a significant improvement of overall health.

The research provides evidence of the various effects of exergaming (on technology acceptance, flow, chronic pain and balance) by designing the standard exercise comparison group using physical movements that were matched with the movements in the exergaming group. It has shown significant reductions in postural sway in older people over time, implying an improvement in balance after a 6-week exergaming intervention. The research was able to show tentative evidence of balance improvement from exergaming due to the significant lower reduction in centre of pressure excursion in the medio-lateral direction during quiet standing in the eyes closed condition in older people who participated in exergaming.

5.5 Study limitations

In both studies, neither the author nor participants were blind to the condition being tested. This may introduce a bias as the presence of the same unblinded assessor could have influenced participants' performance during testing. In the first study, data was collected from a homogeneous group of participants – healthy older people who exercised regularly, did not have any functional or physical limitations, and thus were able to perform all the movements required for the exergaming intervention. In the second study, although the participants were older people with self-reported chronic pain, most were independent-living and fairly fit in their physical gait and performance. Therefore, results came from older people whom, despite having chronic pain, were not too adversely affected with physical or balance impairments, that could be addressed by exercise intervention participation.

The research investigated the effects of exergaming on older people's postural sway during tests of quiet bipedal standing balance. Although this result is an important finding, it cannot be extrapolated to more challenging balance conditions and functional movement. Within current literature there is no consensus as to which test of balance would be regarded the 'gold standard' to assess postural control in healthy adults. It is possible that quiet standing was an insufficiently demanding test for the participants. However, all of the information supplied to the participants emphasised the neutral stance of the researcher and the equipoise in the research question. Interaction between the researcher and participants was kept to a minimum set of instructions. No verbal encouragement was given before or during balance tests. Neither was there feedback on performance after the balance tests.

The author acknowledges that in both studies, the results are based on a limited number of participants. Research drawing from a larger population would be ideal to further validate the outcomes from the two studies. For example, due to the small sample size, it may not have been possible to comprehensively explore the impact of other explanatory variables on older people's intention to use exergaming, or substantiate gender differences in pain outcomes.

5.6 Future recommendations

As discussed before, exergaming is likely to be well received by older people who exercised regularly and those who suffered chronic musculoskeletal pain. The findings of the current thesis showed two prominent variables of technology acceptance (i.e. performance expectancy and effort expectancy) that influenced older people's behavioural intention to use the exergaming technology. Further investigation could be carried out to see how other technology acceptance variables such as self-efficacy and facilitating conditions are associated with behavioural intention, and look into the potential role that gender plays in exergaming acceptance in older people. Previous studies have reported differences in IT use between men and women (Gefen and Straub, 1997; Singh, 2001), and gender differences in gaming preferences (Hartmann and Klimmt, 2006). Although the current thesis was not able to find any gender differences, the possibility that gender influences older people's preferences for exergaming types, duration of activity and gaming strategies is an option to be explored.

In relation to older people's acceptance of exergaming, further research may look into their preferences of exergame types and the design of exergames which have features that appeal to older people, hence giving them motivation to perform exercise while maintaining their enjoyment of playing the game. Technical and usablilty challenges in developing exergames for older people, including training and support, could be addressed, particularly to cover a wider range of users, such as active people in their late fifties, seniors with impairments who are still able to lead an independent life as well as the frail elderly living in care homes.

Although the current thesis found evidence of older people experiencing flow state where levels of flow significantly increased from the start to the end of the intervention, it did not investigate how older people's flow experience influenced their future intention to use the exergaming technology. Therefore, further work could incorporate aspects of flow into modelling older people's behavioural intention to use exergaming.

According to Csikszentmihalyi and Csikszentmihalyi (1988), there are sometimes large differences in the frequency and intensity with which people experience flow. While the thesis found evidence suggestive of older people experiencing flow state while exergaming, further work could investigate individual differences found in the experiencing of flow. This could help to understand how older people could benefit from exergaming. For example, qualitative interviews could be carried out to see how older people respond and react to different aspects of flow during exergaming, such as their concentration during exergaming, or if exergaming could motivate them into modify their behaviour, such as becoming more physically active, or purchasing their own exergaming system.

Flow investigation could also be included in further work investigating balance control in older people. This was not carried on in the current thesis. If being in flow means that one is totally connected in terms of challenge and skills, the next research question concerning flow and balance is – does flow affect how older people ”carry” themselves? Does being in an optimal state of flow contribute to more stable balance? Innovative methods to effectively examine the relationship of flow occurrence and balance in older people would have important clinical benefits. Research could further investigate the association of flow with psychological well-being and physical functioning in old age to provide a better understanding of how older people can improve the quality of their lives.

In view of the evidence of the physical, social and cognitive benefits of exergaming found in the current thesis, it might be worthwhile for future research to consider the influence of exergaming in the management of chronic pain in older people. As the literature also indicates the potential of exergaming as healthy exercise, further investigation may be extended to examine the role of exergaming as a coping strategy for chronic pain management. In this research, self-reported chronic pain was recorded at anatomical sites specified by participants. They were also asked about the presence of chronic pain during physical tasks such as moving up the stairs. These set of pain conditions were not categorised into pain conditions, for example, back, headache, chest, abdomen and orofacial pain. Future research in exergaming might address these pain conditions and occurrences in relation to exergaming participation, for instance investigating the effects of exergaming in older people suffering from only hip pain.

As with other modes of exercise, it is expected that longer duration, greater frequency, and higher intensity (placing the participants at or near their limits of ability) would deliver better results. Although the findings provide preliminary evidence of improved postural sway after exergaming, better examination of balance will require longitudinal data from testing for a longer period. Further investigation of balance could be extended to a population of older people who suffer from adverse balance impairments that are related to chronic pain. Due to the restraints of this PhD, underlying sensory and muscular mechanisms contributing to balance in older people were not addressed. Future research could address these issues. Consequently, the impact of chronic pain on balance and the related effects of well-being and flow are important areas for further research.

5.7 Main conclusions

This research points to several main conclusions:

1. older people are very likely to use the exergaming technology for exercise, if given proper training, instruction and technical support;

2. how likely they are to use exergaming depends on whether they are able to cope with the movements or the games, and how much benefit they can derive from it;

3. experience influences the decisions that older people make. If they found the exergaming experience to be positive, they are more likely to choose to continue using it;

4. it may be possible for older people to experience flow while exergaming, in agreement with Nakamura and Csikszentmihalyi (2002)'s assertion that flow experience is a conscious experience that can be felt by anybody;

5. the incidence of flow state happening during exergaming as reflected in the flow measures showed that it was possible for older people to achieve flow state while partaking in a novel activity that was previously unfamiliar to them;

6. dimensions of flow state during exergaming improves significantly over time. This clearly indicates the association of exergaming with enjoyment or positive affect factors in older people. More exergaming equals more flow;

7. exergaming can facilitate perceived feedback in physical activity;

8. exergaming has a potential role in pain management, as shown in the significant reduction of older people's self-perceived pain intensity;

9. exergaming may contribute to developing a positive sense of self, as demonstrated in the assessment of chronic somatosensory pain where there were significant reduced levels of depressed mood and affiliative feelings at 6-weeks after intervention;

10. older people may need to be exposed to exergaming for an optimal duration, before significant improvements in balance performance can be observed;

11. both exergaming and standard exercise, when performed safely and appropriately, have the potential to improve balance in older people.

Appendix A

Prospective power analyses

Table A.1: Prospective power analyses based on α = 0.05 using equations and tables presented in Clarke-Carter (2010)

Statistical test	df/predictors	Sample size (small ES)	Sample size (medium ES)	Sample size (large ES)
χ^2	1	767 (w = 0.10)	85 (w = 0.3)	30 (w = 0.5)
χ^2	3	1075 (w = 0.1)	120 (w = 0.3)	43 (w = 0.5)
χ^2	6	1350 (w = 0.1)	150 (w = 0.3)	54 (w = 0.5)
Pearson's Correlation (two-tailed tests)	NA	784 (r = 0.1)	85 (r = 0.3)	29 (r = 0.5)
Pearson's Correlation between two samples (two-tailed tests)		1567 (r = 0.1)	177 (r = 0.3)	67 (r = 0.5)
F-ratio in repeated measures ANOVA	1	384 (η^2 = 0.01)	62 (η^2 = 0.059)	25 (η^2 = 0.138)
F-ratio in repeated measures ANOVA	5	214 (η^2 = 0.01)	35 (η^2 = 0.059)	15 (η^2 = 0.138)
F-ratio in repeated measures ANOVA	6	192 (η^2 = 0.01)	33 (η^2 = 0.059)	13 (η^2 = 0.138)
Multiple regression	1	417 (R^2 = .0196)	54 (R^2 = .13)	25 (R^2 = .26)
Multiple regression	2	484 (R^2 = .0196)	69 (R^2 = .13)	30 (R^2 = .26)
Multiple regression	3	563 (R^2 = .0196)	78 (R^2 = .13)	36 (R^2 = .26)
Multiple regression	4	618 (R^2 = .0196)	85 (R^2 = .13)	39 (R^2 = .26)
Multiple regression†	5	647 (R^2 = .0196)	92 (R^2 = .13)	43 (R^2 = .26)
Multiple regression	6	700 (R^2 = .0196)	99 (R^2 = .13)	46 (R^2 = .26)
Multiple regression	8	750 (R^2 = .0196)	109 (R^2 = .13)	52 (R^2 = .26)
Multiple regression	10	827 (R^2 = .0196)	118 (R^2 = .13)	57 (R^2 = .26)
Multiple regression	12	893 (R^2 = .0196)	129 (R^2 = .13)	62 (R^2 = .26)

Note: Where precise *n* was not available, linear interpolation was calculated using the formula:

$$\text{Required } n_a = \text{lower n} + \left(\frac{\text{desired power - lower power}}{\text{upper power - lower power}}\right) \times \text{upper n - lower n}$$

†: When the table for 5 predictors was not available, G*Power (Faul et al., 2007) was used to calculate the sample size.

Appendix B

Measurement scales

B.1 Modified Technology Acceptance Questionnaire for the experimental group

You are asked to indicate your level of agreement or disagreement with each of the statements below by circling one of the numbers on the scale of 1-7, ranging from Strongly Disagree to Strongly Agree. When completing this for the first time it will be before you begin your exercise programme so please base your answers on your expectations or initial thoughts about the virtual reality system.

	Strongly disagree						Strongly agree
I would find the virtual reality system useful to perform exercise	1	2	3	4	5	6	7
Using the virtual reality system makes it easier to do my exercise	1	2	3	4	5	6	7
Using the virtual reality system increases the effectiveness of my exercise	1	2	3	4	5	6	7
My interaction with the virtual reality system would be clear and understandable	1	2	3	4	5	6	7
It would be easy for me to become skilful using the virtual reality system	1	2	3	4	5	6	7
I would find the virtual reality system easy to use	1	2	3	4	5	6	7
Learning to use the virtual reality system for exercise is easy for me	1	2	3	4	5	6	7
People who influence my behaviour think that I should use the virtual reality system	1	2	3	4	5	6	7
People who are important to me think that I should use the virtual reality system	1	2	3	4	5	6	7

I have the physical capabilities necessary to use the virtual reality system	1	2	3	4	5	6	7
I have the knowledge necessary to use the virtual reality system for exercise purposes	1	2	3	4	5	6	7
I could complete my exercise using the virtual reality system...							
If there was no one around to tell me what to do as I go	1	2	3	4	5	6	7
If I could call someone for help if I got stuck	1	2	3	4	5	6	7
If I have a lot of time to exercise using the virtual reality system	1	2	3	4	5	6	7
If I just have an online help facility for assistance	1	2	3	4	5	6	7

B.2 Modified Technology Acceptance Questionnaire for the control group

You are asked to indicate your level of agreement or disagreement with each of the statements below by circling one of the numbers on the scale of 1-7, ranging from Strongly Disagree to Strongly Agree. When completing this for the first time it will be before you begin your exercise programme so please base your answers on your expectations or initial thoughts about the virtual reality system.

	Strongly disagree						Strongly agree
I would find standard exercises useful for exercising	1	2	3	4	5	6	7
Using standard exercise makes it easier to do my exercise	1	2	3	4	5	6	7
Using standard exercise increases the effectiveness of my exercise	1	2	3	4	5	6	7
My interaction with standard exercise would be clear and understandable	1	2	3	4	5	6	7
It would be easy for me to become skilful using standard exercise	1	2	3	4	5	6	7
I would find standard exercises easy to use	1	2	3	4	5	6	7
Learning to do standard exercise is easy for me	1	2	3	4	5	6	7
People who influence my behaviour think that I should do standard exercise	1	2	3	4	5	6	7

People who are important to me think that I should do standard exercise	1	2	3	4	5	6	7
I have the physical capabilities necessary to perform standard exercise	1	2	3	4	5	6	7
I have the knowledge necessary to do standard exercises for exercise purposes	1	2	3	4	5	6	7
I could complete my exercise using standard exercise...							
If there was no one around to tell me what to do as I go	1	2	3	4	5	6	7
If I could call someone for help if I got stuck	1	2	3	4	5	6	7
If I have a lot of time to exercise using the virtual reality system	1	2	3	4	5	6	7
If I just have an online help facility for assistance	1	2	3	4	5	6	7

Table B.3: Original questionnaire from the Unified Theory of Acceptance and Use Technology (UTAUT) (Venkatesh et al., 2003)

Performance expectancy	
U6	I would find the system useful in my job.
RA1	Using the system enables me to accomplish tasks more quickly.
RA5	Using the system increases my productivity.
OE7	If I use the system, I will increase my chances of getting a raise.
Effort expectancy	
EOU3:	My interaction with the system would be clear and understandable.
EOU5:	It would be easy for me to become skilful at using the system.
EOU6:	I would find the system easy to use.
EU4:	Learning to operate the system is easy for me.
Attitude toward using technology	
A1:	Using the system is a bad/good idea.
AF1:	The system makes work more interesting.
AF2:	Working with the system is fun.
Affect 1:	I like working with the system.
Social influence	
SN1:	People who influence my behaviour think that I should use the system.
SN2:	People who are important to me think that I should use the system.
SF2:	The senior management of this business has been helpful in the use of the system.
SF4:	In general, the organisation has supported the use of the system.
Facilitating conditions	
PBC2:	I have the resources necessary to use the system.
PBC3:	I have the knowledge necessary to use the system.
PBC5:	The system is not compatible with other systems I use.
FC3:	A specific person (or group) is available for assistance with system difficulties.

Self-efficacy

I could complete a job or task using the system...

SE1: If there was no one around to tell me what to do as I go.

SE4: If I could call someone for help if I got stuck.

SE6: If I had a lot of time to complete the job for which the software was provided.

SE7: If I had just the built-in help facility for assistance.

Anxiety

ANX1: I feel apprehensive about using the system.

ANX2: It scares me to think that I could lose a lot of information using the system by hitting the wrong key.

ANX3: I hesitate to use the system for fear of making mistakes I cannot correct.

ANX4: The system is somewhat intimidating to me.

Behavioural intention to use the system

BI1: I intend to use the system in the next <n>months.

BI2: I predict I would use the system in the next <n>months.

BI3: I plan to use the system in the next <n>months.

B.3 The Flow State Scale (Jackson and Marsh, 1996)

You are asked to indicate your level of agreement or disagreement with each of the statements below by circling one of the numbers on the scale of 1-5, ranging from Strongly Disagree to Strongly Agree. When completing this for the first time it will be after your first exercise session, so please base your answers on your expectations or initial thoughts about exercising. You will also be required to complete this questionnaire again at the end of the intervention.

1.	I was challenged, but I believed my skills would allow me to meet the challenge.	1	2	3	4	5
2.	I made the correct movements without thinking about trying to do so.	1	2	3	4	5
3.	I knew clearly what I wanted to do.	1	2	3	4	5
4.	It was really clear to me that I was doing well.	1	2	3	4	5
5.	My attention was focused entirely on what I was doing.	1	2	3	4	5
6.	I felt in total control of what I was doing.	1	2	3	4	5
7.	I was not concerned with what others may have been thinking of me.	1	2	3	4	5
8.	Time seemed to alter (either slowed down or speeded up).	1	2	3	4	5
9.	I really enjoyed the experience.	1	2	3	4	5
10.	My abilities matched the high challenge of the situation.	1	2	3	4	5
11.	Things just seemed to be happening automatically.	1	2	3	4	5
12.	I had a strong sense of what I wanted to do.	1	2	3	4	5
13.	I was aware of how well I was performing.	1	2	3	4	5
14.	It was no effort to keep my mind on what was happening.	1	2	3	4	5
15.	I felt like I could control what I was doing.	1	2	3	4	5
16.	I was not worried about my performance during the event.	1	2	3	4	5
17.	The way time passed seemed to be different from normal.	1	2	3	4	5
18.	I loved the feeling of that performance and want to capture it again.	1	2	3	4	5
19.	I felt I was competent enough to meet the high demands of the situation.	1	2	3	4	5

(Continued on next page)

Table B.4 – continued from the previous page

20.	I performed automatically.	1	2	3	4	5
21.	I knew what I wanted to achieve.	1	2	3	4	5
22.	I had a good idea while I was performing about how well I was doing.	1	2	3	4	5
23.	I had total concentration.	1	2	3	4	5
24.	I had a feeling of total control.	1	2	3	4	5
25.	I was not concerned with how I was presenting myself.	1	2	3	4	5
26.	It felt like time stopped while I was performing.	1	2	3	4	5
27.	The experience left me feeling great.	1	2	3	4	5
28.	The challenge and my skills were at an equally high level.	1	2	3	4	5
29.	I did things spontaneously and automatically without having to think.	1	2	3	4	5
30.	My goals were clearly defined.	1	2	3	4	5
31.	I could tell by the way I was performing how well I was doing.	1	2	3	4	5
32.	I was completely focused on the task at hand.	1	2	3	4	5
33.	I felt in total control of my body.	1	2	3	4	5
34.	I was not worried about what others may have been thinking of me.	1	2	3	4	5
35.	At times, it almost seemed like things were happening in slow motion.	1	2	3	4	5
36.	I found the experience extremely rewarding.	1	2	3	4	5

B.4 WHODAS-II

H1	How do you rate your overall health in the past 30 days	Very good	Good	Moderate	Bad	Very bad

This questionnaire asks about difficulties due to health conditions. Health conditions include diseases or illnesses, other health problems that may be short or long lasting, injuries, mental or emotional problems, and problems with alcohol or drugs. Think back over the last 30 days and answer these questions thinking about how much difficulty you had doing the following activities. For each question, please circle only one response.

In the past 30 days, how much difficulty did you have in:

Understanding and communicating

D1.1	Concentrating on doing something for ten minutes?	None	Mild	Moderate	Severe	Extreme/ cannot do
D1.2	Remembering to do important things?	None	Mild	Moderate	Severe	Extreme/ cannot do
D1.3	Analyzing and finding solutions to problems in day to day life?	None	Mild	Moderate	Severe	Extreme/ cannot do
D1.4	Learning a new task, for example, learning how to get to a new place?	None	Mild	Moderate	Severe	Extreme/ cannot do
D1.5	Generally understanding what people say?	None	Mild	Moderate	Severe	Extreme/ cannot do

D1.6	Starting and maintaining a conversation?	None	Mild	Moderate	Severe	Extreme/ cannot do

Getting around

D2.1	Standing for long periods such as 30 minutes?	None	Mild	Moderate	Severe	Extreme/ cannot do
D2.2	Standing up from sitting down?	None	Mild	Moderate	Severe	Extreme/ cannot do
D2.3	Moving around inside your home?	None	Mild	Moderate	Severe	Extreme/ cannot do
D2.4	Getting out of your home?	None	Mild	Moderate	Severe	Extreme/ cannot do
D2.5	Walking a long distance such as a mile (or equivalent)?	None	Mild	Moderate	Severe	Extreme/ cannot do

Self-care

D3.1	Washing your whole body?	None	Mild	Moderate	Severe	Extreme/ cannot do
D3.2	Getting dressed?	None	Mild	Moderate	Severe	Extreme/ cannot do

In the past 30 days, how much difficulty did you have in:

D3.3	Eating?	None	Mild	Moderate	Severe	Extreme/ cannot do
D3.4	Staying by yourself for a few days?	None	Mild	Moderate	Severe	Extreme/ cannot do

Getting along with people

D4.1	Dealing with people you do not know?	None	Mild	Moderate	Severe	Extreme/ cannot do
D4.2	Maintaining a friendship?	None	Mild	Moderate	Severe	Extreme/ cannot do

D4.3	Getting along with people who are close to you?	None	Mild	Moderate	Severe	Extreme/ cannot do
D4.4	Making new friends?	None	Mild	Moderate	Severe	Extreme/ cannot do
D4.5	Sexual activities?	None	Mild	Moderate	Severe	Extreme/ cannot do

Life activities

D5.1	Taking care of your household responsibilities?	None	Mild	Moderate	Severe	Extreme/ cannot do
D5.2	Doing most important household tasks well?	None	Mild	Moderate	Severe	Extreme/ cannot do
D5.3	Getting all the household work done that you needed to do?	None	Mild	Moderate	Severe	Extreme/ cannot do
D5.4	Getting your household work done as quickly as needed?	None	Mild	Moderate	Severe	Extreme/ cannot do

IF YOU WORK (PAID, NON-PAID, SELF EMPLOYED) OR GO TO SCHOOL, COMPLETE QUESTIONS D5.5–D5.8 BELOW. OTHERWISE, SKIP TO D6.1 BELOW.

In the past 30 days, how much difficulty did you have in:

D5.5	Your day to day work/school?	None	Mild	Moderate	Severe	Extreme/ cannot do
D5.6	Doing your most important work/school tasks well?	None	Mild	Moderate	Severe	Extreme/ cannot do
D5.7	Getting all the work done that you need to do?	None	Mild	Moderate	Severe	Extreme/ cannot do
D5.8	Getting all the work done as quickly as needed?	None	Mild	Moderate	Severe	Extreme/ cannot do

In the past 30 days:

Participation in society

D6.1	How much of a problem did you have in joining in community activities (for example, festivities, religious or other activities) in the same way as anyone else can?	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.2	How much of a problem did you have because of barriers or hindrances in the world around you?	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.3	How much of a problem did you have living with dignity because of the attitudes and actions of others	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.4	How much time did you spend on your health condition, or its consequences	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.5	How much have you been emotionally affected by your health condition	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.6	How much has your health been a drain on the financial resources of you or your family	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.7	How much of a problem did your family have because of your health problems?	None	Mild	Moderate	Severe	Extreme/ cannot do
D6.8	How much of a problem did you have in doing things by yourself for relaxation or pleasure?	None	Mild	Moderate	Severe	Extreme/ cannot do

H2	Overall, how much did these difficulties interfere with your life?	None	Mild	Moderate	Severe	Extreme/ cannot do

H3	Overall, in the past 30 days, how many days were these difficulties present?	RECORD NUMBER OF DAYS ___ /___
H4	In the past 30 days, for how many days were you totally unable to carry out your usual activities or work because of any health condition?	RECORD NUMBER OF DAYS ___ /___
H5	In the past 30 days, not counting the days that you were totally unable, for how many days did you cut back or reduce your usual activities or work because of any health condition?	RECORD NUMBER OF DAYS ___ /___

This completes the questionnaire. Thank you.

B.5 Multidimensional Affect and Pain Survey (MAPS)

Instructions:

We are interested in your feelings of discomfortt, pain and emotion. Here are 101 statements, containing words which describe painful and non-painful sensations as well as negative and positive emotions. For each statement please decide how closely each word comes to describing how and what you are feeling right now.

Here is the rating scale you will be using:

NOT AT ALL					VERY MUCH SO
0	1	2	3	4	5

If NOT AT ALL describes your experience, you would circle 0; if VERY MUCH SO describes your experience, circle 5. If your response is in between, circle a number between 1 and 4. Use only whole numbers from 0 to 5 for each response. If you are not sure of the meaning of a word make your best guess and put a question mark next to the number in the left margin. **It is essential that each of the 101 items receive a rating.**

Please circle the appropriate response.

1)	The sensation and/or pain is ITCHY.	0	1	2	3	4	5
2)	The sensation and/or pain is CRAWLING.	0	1	2	3	4	5

3)	The sensation and/or pain is TINGLING.	0	1	2	3	4	5
4)	The pain is INTERMITTENT.	0	1	2	3	4	5
5)	The pain is MILD.	0	1	2	3	4	5
6)	The sensation and/or pain is TIGHT.	0	1	2	3	4	5
7)	The pain is SORE.	0	1	2	3	4	5
8)	The sensation and/or pain is NAUSEATING.	0	1	2	3	4	5
9)	The sensation and/or pain is DISTURBING.	0	1	2	3	4	5
10)	The sensation and/or pain is DISTRACTING.	0	1	2	3	4	5
11)	The sensation is HOT.	0	1	2	3	4	5
12)	The pain is WORSENING.	0	1	2	3	4	5
13)	The pain is PERVASIVE.	0	1	2	3	4	5
14)	The pain is NASTY.	0	1	2	3	4	5
15)	The pain is OVERWHELMING.	0	1	2	3	4	5
16)	The pain is POUNDING.	0	1	2	3	4	5

17)	The pain is SMARTING.	0	1	2	3	4	5
18)	The pain is GNAWING.	0	1	2	3	4	5
19)	The pain is PENETRATING.	0	1	2	3	4	5
20)	The pain is TEARING.	0	1	2	3	4	5
21)	The pain is SHARP.	0	1	2	3	4	5
22)	The sensation and/or pain is PULLING.	0	1	2	3	4	5
23)	The pain is CRUSHING.	0	1	2	3	4	5
24)	The pain is SQUEEZING.	0	1	2	3	4	5
25)	The pain is CRAMPING.	0	1	2	3	4	5
26)	The sensation and/or pain is SUFFOCATING.	0	1	2	3	4	5
27)	The sensation is COOL.	0	1	2	3	4	5
28)	The sensation and/or pain is NUMBING.	0	1	2	3	4	5
29)	The pain is RESTRICTED.	0	1	2	3	4	5
30)	I am SUFFERING.	0	1	2	3	4	5

31)	I feel MISERABLE.	0	1	2	3	4	5
32)	I feel REJECTED.	0	1	2	3	4	5
33)	I feel DISCOURAGED.	0	1	2	3	4	5
34)	I feel NEGLIGENT.	0	1	2	3	4	5
35)	I feel OUTRAGED.	0	1	2	3	4	5
36)	I feel UPSET.	0	1	2	3	4	5
37)	I feel ANXIOUS.	0	1	2	3	4	5
38)	The sensation and/or pain is STARTLING.	0	1	2	3	4	5
39)	I feel TERRIFIED.	0	1	2	3	4	5
40)	I am STOICAL.	0	1	2	3	4	5
41)	The pain is TIRING.	0	1	2	3	4	5
42)	I feel SLUGGISH.	0	1	2	3	4	5
43)	The pain is MANAGEABLE.	0	1	2	3	4	5
44)	I am INVOLVED.	0	1	2	3	4	5

45)	I feel VIGOROUS.	0	1	2	3	4	5
46)	I feel AFFECTIONATE.	0	1	2	3	4	5
47)	I feel SYMPATHETIC.	0	1	2	3	4	5
48)	I feel ENCOURAGED.	0	1	2	3	4	5
49)	I feel HAPPY.	0	1	2	3	4	5
50)	I feel CONTENTED.	0	1	2	3	4	5
51)	I feel RELAXED.	0	1	2	3	4	5
52)	The sensation and/or pain is IRRITATING.	0	1	2	3	4	5
53)	The sensation and/or pain is TICKLING.	0	1	2	3	4	5
54)	The pain is FLICKERING.	0	1	2	3	4	5
55)	The pain is DULL.	0	1	2	3	4	5
56)	The sensation and/or pain is STIFF.	0	1	2	3	4	5
57)	The pain is ACHING.	0	1	2	3	4	5
58)	The sensation and/or pain is DISGUSTING.	0	1	2	3	4	5

59)	The sensation and/or pain is DISTRESSING.	0	1	2	3	4	5
60)	The sensation and/or pain is BOTHERSOME.	0	1	2	3	4	5
61)	The pain is BURNING.	0	1	2	3	4	5
62)	The pain is SPREADING.	0	1	2	3	4	5
63)	The pain is PERSISTENT.	0	1	2	3	4	5
64)	The pain is VICIOUS.	0	1	2	3	4	5
65)	The pain is EXCRUCIATING.	0	1	2	3	4	5
66)	The pain is THROBBING.	0	1	2	3	4	5
67)	The pain is STINGING.	0	1	2	3	4	5
68)	The pain is BITING.	0	1	2	3	4	5
69)	The pain is DEEP.	0	1	2	3	4	5
70)	The pain is SPLITTING.	0	1	2	3	4	5
71)	The pain is STABBING.	0	1	2	3	4	5
72)	The pain is SHOOTING.	0	1	2	3	4	5

73)	The sensation and/or pain is TUGGING.	0	1	2	3	4	5
74)	The pain is GRINDING.	0	1	2	3	4	5
75)	The pain is PRESSING.	0	1	2	3	4	5
76)	The pain is CHOKING.	0	1	2	3	4	5
77)	The sensation and/or pain is COLD.	0	1	2	3	4	5
78)	The sensation is NUMB.	0	1	2	3	4	5
79)	The sensation and/or pain is LOCALISED .	0	1	2	3	4	5
80)	I am AILING.	0	1	2	3	4	5
81)	I feel LOUSY.	0	1	2	3	4	5
82)	I feel LONELY.	0	1	2	3	4	5
83)	I feel DEPRESSED.	0	1	2	3	4	5
84)	I feel GUILTY.	0	1	2	3	4	5
85)	I feel ANGRY.	0	1	2	3	4	5
86)	I feel ANNOYED.	0	1	2	3	4	5

87)	I feel STRESSED.	0	1	2	3	4	5
88)	The sensation/pain is ALARMING.	0	1	2	3	4	5
89)	I feel FRANTIC.	0	1	2	3	4	5
90)	I feel APATHETIC.	0	1	2	3	4	5
91)	The pain is EXHAUSTING.	0	1	2	3	4	5
92)	I feel SLEEPY.	0	1	2	3	4	5
93)	The pain is CURABLE.	0	1	2	3	4	5
94)	I feel INTERESTED.	0	1	2	3	4	5
95)	I feel ACTIVE.	0	1	2	3	4	5
96)	I feel LOVED.	0	1	2	3	4	5
97)	I feel FORGIVING.	0	1	2	3	4	5
98)	I feel HOPEFUL.	0	1	2	3	4	5
99)	I feel CHEERFUL.	0	1	2	3	4	5
100)	I feel SATISFIED.	0	1	2	3	4	5

101)	I feel CALM.	0 1 2 3 4 5

Table B.9: Pain classification according to Leveille et al. 2002

Class	NRS	Description	
1	≥ 4	3 sites	upper body, lower extremity, axial (widespread)
2	≥ 4	1 site	lower extremity
3	< 4	1 site	no pain or mild
4	Other pain not fitting the above		

Note. ≥ 4: moderate to severe pain

Appendix C

Physical and mental effort exertion scales

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very. Very hard
20	

Figure C.1: Borg's Scale of Rating Perceived Exertion (RPE) Borg (1970*a*)

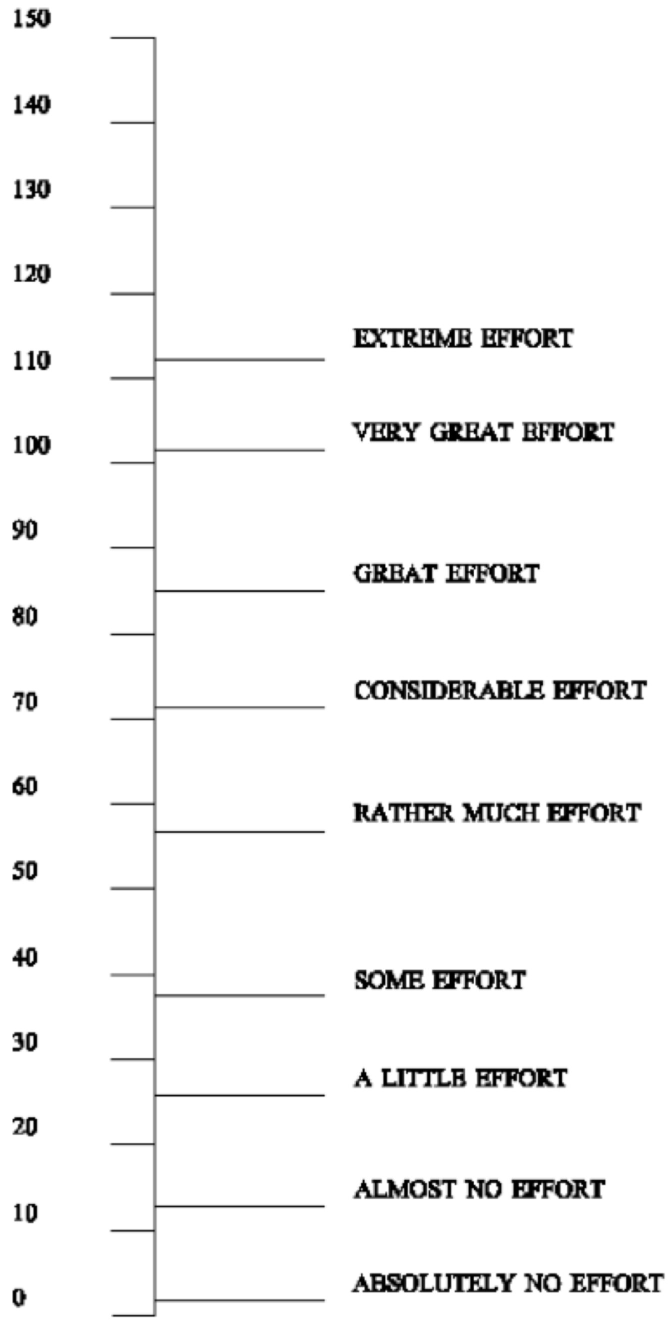

Figure C.2: Subjective Mental Effort Questionnaire (SMEQ) Zijlstra (1993)

Appendix D

Study 1: Information

D.1 Letter of Approval for study 059/09

PRIVATE AND CONFIDENTIAL

Direct Line: 01642 342750

20 May 2009.

Denis Martin

School of Health & Social Care

University of Teesside

Dear Denis

Study 059/09 – The acceptance and experience of virtual reality enhanced exercise in older people Researcher: Yvonne Khoo Supervisor: Denis Martin

Decision: Approved

Thank you for submitting an amended application pack. I am pleased to confirm that the comments raised by the School of Health & Social Care Research Governance and Ethics Committee have been addressed in your amended application pack and your study has been approved through Chair's Action on 19 May 2009. Your study may proceed as it was described in your approved application pack.

Please note:

Where applicable, your study may only proceed when you have also received written approval from any other ethical committee (e.g. NRES) and operational / management structures relevant (e.g. Local NHS R&D). A copy of this approval letter must be attached to applications to any other ethical committee. If applicable please forward to me a copy of the approval letter from NRES before proceeding with the study.

In all cases, should you wish to make any substantial amendment to the protocol detailed, or supporting documentation included, in your approved application pack (other than those required as urgent safety measures) you must obtain written approval for those, from myself and all other relevant bodies, prior to implementing any amendment. Details of any changes made as urgent safety measures must be provided in writing to myself and all other relevant bodies as soon as possible after the relevant event; the study should not continue until written approval for those changes has been obtained from myself and all other relevant bodies.

On behalf of the School of Health & Social Care Research Governance and Ethics Committee please accept my best wishes for success in completing your study.

Yours sincerely

Dr. Alasdair MacSween

Chair

Research Governance and Ethics Committee

School of Health & Social Care

D.2 Study 1: Recruitment pamphlet

Are you aged 50 or over?

Do you exercise?

Would you try a different form of exercise?

If your answers to questions above are YES, please consider taking part in a research project. The project is being undertaken as part of a PhD titled "Virtual reality augmented rehabilitation to improve postural stability in older people with chronic pain" at the University of Teesside and is trying to explore how people over the age of fifty feel about exercising in a virtual reality environment.

If you decide to participate, you will be asked to attend the University of Teesside twice weekly over the course of three weeks for a series of exercise sessions using a virtual reality exercise system called IREX^{TM} (Interactive Rehabilitation Exercise System). The IREX^{TM} system is similar to TV weather forecasts where the forecaster is shown standing in front of and interacting with, a changing weather map.

This project has been approved by the School of Health & Social Care Research Governance and Ethics Committee.

If you are interested, please contact me for further information.

Yvonne Khoo

Email: H8085063@tees.ac.uk Tel: 01642 384697

D.3 Study 1: Reply slip

If you are interested in taking part or would like to ask any questions of me or my supervisor, please print your name here –

By post – please tell me the address and what time/hour(s) of day –

By phone – please tell me the number and what time/hour(s) of day –

By email – please tell me your email address –

Please post this reply slip to me at:

Yvonne Khoo

Middesbrough Tower (Health Phoenix 2.09)

Teesside University

Borough Road

TS1 3BA.

Or email me at H8085063@tees.ac.uk

Or telephone me at 01642 384697

D.4 Study 1: Participant information sheet (PIS)

Title of study: The acceptance and experience of virtual reality enhanced exercise among older people

Researcher: Ms Yvonne Khoo

Study identification Number 059/09

Purpose of the Study

My name is Yvonne Khoo and I am a Full Time PhD student in the School of Health and Social Care at the University of Teesside. As part of my PhD I am investigating what people over the age of fifty think about doing exercise using a type of virtual reality technology. The virtual reality system I am using is called the IREX^{TM} (Interactive Rehabilitation Exercise System).

Activity with the IREX^{TM} is like playing a video game. The only difference is that an image of yourself is projected in the television screen in front of you, and the advantage is that you do not need to wear, touch, hold or operate any electrical or mechanical devices such as goggles or joysticks. Before you decide whether or not to participate please read this Information Sheet and if you have any questions please do not hesitate to ask.

Why have I been invited to consider participating?

You have been invited to take part in this study because you meet particular criteria. This means that you must be:

- Aged 50 years or over
- Currently participating in a community exercise group
- Able to walk unassisted
- Able to read and write English

Also it is important that you don't have any of the criteria listed below:

- Any condition or injury, past or present, which would rule out participation in the exercises under study
- Musculoskeletal injury within the last 12 weeks
- Awaiting or currently undergoing, or having taken part in within the last 12 months, rehabilitation for any musculoskeletal, neurological or cardiorespiratory health conditions.

What happens if I decide to take part?

You will be asked to attend the Therapy Lab in the Constantine Building at Teesside University twice a week for a period of three weeks. Each session will take approximately 40 minutes. Every effort will be made to arrange the dates and times when you attend to suit your schedule, within normal working hours.

At each session you will be asked to play five virtual reality games using the IREX^{TM} system. You will receive a Written Instruction Sheet (a copy is attached) telling you about what is involved in each game. I will also demonstrate all the games you will be asked to try before you begin. You will only begin each session when you are both confident that you know what you are to do and that you are able to perform the physical movements involved.

At the start of the three-week period you will be asked to fill in one questionnaire in relation to the virtual reality exercise session.

You will also be asked to fill in two questionnaires with respect to your thoughts, feelings and experiences responding to the continuum of information between you and the virtual system before and after every session. The researcher will then ask you a few questions concerning your physical or mental efforts which you experienced as you engaged in the IREX^{TM} session.

In all the games all you do is stand in front of a green cloth and you will see yourself on a TV screen placed in front of you. None of your movements need to be fast or big - you move only as much, or as little as you wish to, and you are always standing on level ground in all games, in your own shoes. There is no other equipment involved and no images of you are recorded. IREX^{TM} games are not like virtual reality games you may have seen, or played, in arcades where you actually sit in a car, or stand on a simulated snowboard, with IREX^{TM} you just stand on the floor and move and your image is projected on the television screen into the game and the images are controlled by your movements.

These games have all been programmed to facilitate exercises for rehabilitation purposes. They are used in clinics in the USA, Europe and Asia with different patient groups and no instances of injury or problems have been reported.

Each game will last for 45 seconds. There will be a gap of 15 seconds between each game. There will be a two minute rest period after the four games have been performed. You will then be asked to do the five games again. In total, each set of five exercises will be performed three times. This will constitute one session. You will be asked to come back another day so that you will have completed a total of two sessions in a three week period.

What are the possible benefits of taking part in the study?

These games have been designed to facilitate exercises and to encourage physical movements for rehabilitation purposes. However, it is unlikely that you will experience any direct benefits from this short period of activity as you already do some exercise. It is possible that you may feel some benefit in your balance and muscle control, and find some improvement in your mental faculties where physicalÐmental coordination is concerned.

What are the possible risks involved in taking part in the study?

In the assessment of the team involved in this project – I and my supervisors - the risks are minimal. For healthy people who meet the eligibility criteria the exercises involved are not strenuous. At all times you will exercise at your own pace and within your own comfortable range. The exercises are always carried out with both feet on a level surface so there is very little chance of falling over or slipping. No equipment is involved in the exercises other than the IREX^{TM} system and large movements are not required.

Expenses and Payments

As this study is being undertaken as part of a PhD studentship I regret that I am unable to offer any payment or reimburse any expense incurred.

What happens if something goes wrong?

This study is covered by the University's Insurance Policies. If you believe that you have been harmed in any way by taking part in this study, you have the right to pursue a complaint. We would advise that you contact the Assistant Dean for Research in the School, Prof. Janet Shucksmith (J.Shucksmith@tees.ac.uk) in the first instance if you should have any complaints about the study.

Who has reviewed this study?

This project has been reviewed and approved by the School of Health & Social Care Research Governance and Ethics Committee.

Can I withdraw from the study if I change my mind?

Your participation in this study is voluntary and you can stop the data collection process at any time you wish to without giving any reason and none of your rights will be affected.

If you would like to withdraw after the data has been collected you can withdraw at any point up until 16th June 2009 when I will begin the data analysis. Again if you choose to withdraw your data after it is collected you do not need to give any reason and none of your rights will be affected. All you need do is quote your unique study identity number (which I have written on the top right hand corner of this sheet) to my Director of Studies, Prof. Denis Martin (whose contact details are at the end of this sheet) and your data will be removed and destroyed.

Confidentiality, Anonymity and Data Storage.

All information collected during this study will be stored in accordance with the Data Protection Acts (1984, 1998). Your Consent Form will be stored in a locked filing cabinet housed in my Director of Studies' office in the Parkside West Offices building of the University of Teesside. Hard copies of the anonymised data will be kept in a separate locked filing cabinet in my office in the Parkside West Offices building of the University of Teesside. Electronic files containing the anonymised data will be kept on a password protected server at the University of Teesside. The anonymised data collected during this study will be held securely (as described above) for 5 years and will not be used for any purpose other than as described in this Information Sheet unless it is for another research project which an appropriate research ethics committee has approved.

Access to the study materials and data will be restricted to members of the research team: myself and Prof. Denis Martin, Prof. Paul van Schaik, Dr Alasdair MacSween and Dr John Dixon who are all full time members of staff at University of Teesside.

How will the data be used?

The results of this study will be included in my PhD thesis, publications in peer reviewed journals and conference presentations. At all times data and results will be anonymous and at no time will your identity or any other identifiable information be revealed unless required by law.

Thank you for taking the time to read this information sheet.

If you have any questions please feel free to contact my Director of Studies:

Prof. Denis Martin, DPhil.

Parkside West Offices,

University of Teesside

01642 382754

Email: d.martin@tees.ac.uk

EXERCISE INSTRUCTION SHEET: The How-To Manual

Dear participant,

You will be invited to play a series of five games in each session. You will be asked to do each game three times in each session.

1. Volleyball

You will see a simulated beach setting with a robot opponent standing opposite you.

Figure D.1: The virtual beach environment of the IREX^{TM} volleyball application

What to do:

Land the ball in your opponentÕs court or outside your court!

How to play:

Either move your body, shoulder or touch the volleyball by hand.

Tip:

Smoother movements allow better contact with the ball!

2. Sharkbait

You will see yourself virtually deep-sea diving with sea creatures! You donÕt even have to wear any diving gear!

Figure D.2: The virtual sea environment of the IREX^{TM} Sharkbait application

What to do:

Catch as many stars as you can!

How to play:

Lean side-by-side, crouch down or raising your arms.

To move sideways quickly, step to the side.

Remember that if you meet a shark, it will virtually swallow you and expel you out of its mouth. Contact with an electric eel virtually temporarily disable your movement.

Tip:

When you have got the hang of *navigating*, the deep sea is all yours!

3. Formula Racing

You will see yourself virtually driving in a Grand Prix. The course of the track is also visible to you.

What to do:

Drive through the racecourse as best as you can!

Figure D.3: The virtual IREX^{TM} formula racing application

How to play:

Steer by stepping to the right or left, by moving your body to the side, or by moving one arm at a time.

Tip: Try standing on one leg at a time!

4. Snowboarding

You will see a red silhouette of yourself standing on a snowboard, coming down a narrow slope, and a virtual image of yourself when you cross the finish line.

Figure D.4: The virtual beach IREX^{TM} snowboarding application

What to do:

Make as many jumps as possible and avoid hitting other objects!

How to play:

Begin by stepping sideways until you are centred over the snowboard.

Lean to either side, or move your arm to one side.

Tip:

A good centred position on the snowboard allows easier navigation!

5. IREX^{TM} Soccer game

You will virtually be a soccer goalkeeper!

Figure D.5: The virtual IREX^{TM} soccer application

What to do:

Protect your goalpost! Do not let any balls score on the net behind you!

How to play:

Keep the balls away by using moving either any part of your body or shoulder.

Tip:

Starting with a good stance will allow better balance control!

Thank You for Your Participation

D.5 Study 1: Consent form

Title: Acceptance and experience of virtual-reality-enhanced exercise in older people

Researcher: Ms Yvonne Khoo

Please initial these boxes to show you agree with the statements.

1. I confirm that I have read and understand the Participant Information Sheet dated 16th May 2009 for the above named study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that the data collected during the study will be anonymised and only those members of the study team named on the information sheet, who need to see it, in order to complete the study, will be allowed to see it. ☐
3. I understand that the data relating to me will be kept confidential. No information will be released or printed that would identify me unless required by law. ☐
4. I agree to this Consent Form being kept in a locked filing cabinet and hard copies of the anonymised data being held in a separate locked filing cabinet housed in different offices in the Parkside West Offices building of Teesside University. ☐
5. I agree to the electronic files containing the anonymised data to be kept on a password protected server at Teesside University. ☐
6. I am aware that participation in this study is voluntary and I have the right to withdraw at any point until 16th August 2009. If I choose to withdraw I do not have to give a reason and none of my rights will be affected. ☐
7. I confirm that I am free of all exclusion criteria and meet the inclusion criteria as stated on the information sheet for this study. ☐

8. I agree that the anonymised data collected on me during the study will be held securely (as described in the information sheet and in points Four and Five) for five years, and that it may be used for future research only if an appropriate ethics committee has approached that research. ☐

9. I agree to take part in the study named on the other side of this form. ☐

Name of participant	Date	Signature

Name of researcher	Date	Signature

D.6 Study 1: Demographic data collection form

Name:	
Year of birth:	
Gender:	
Address: Postcode:	
Telephone Numbers:	
Email address:	
Height:	
Weight :	

Are you participating in community exercise?

YES / NO

If yes, please state type of/and duration of exercise:

Table D.2: Coding system for themes derived from content analysis of responses from healthy older people's experience of exergaming

	Theme	Code	Description
1	Enjoyment	1	yes (enjoyable)
		2	no (slightly frustrating, baffling)
		88	not mentioned
2	Mentally challenging	1	yes (needs to concentrate)
		2	no (little effort needed, easy)
		88	not mentioned
4	Loss of time consciousness	1	yes (time passed by very quickly)
		2	no (didn't think about it at all)
		88	not mentioned
5	Self improvement	1	yes (getting better, more skilful, more confident
		2	no (getting worse or none)
		88	not mentioned
6	Feeling of ease	1	yes (relaxed, no strain)
		2	no (muscles aching, tiring)
		88	not mentioned
7	Adapting to VR	1	yes (adjusting to the spatial perspective, working out ways to win)
		2	no (still not used to it)
		88	not mentioned
8	Limitations of VR technology	1	yes (noticed the lapse in motion capture)
		2	no (did not notice any lapse in motion capture)
		88	not mentioned
9	Perceived benefits of VR	1	psychological and/or physical benefit
		2	beneficial for indoor use
		88	not mentioned
10	Behavioural intention to use	1	yes (would recommend/use)
		2	no (not likely)
		88	not mentioned

Appendix E

Content analysis (Study 1)

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
Enjoyable	
Yes (enjoyable)	"It was good fun trying all the games. I thought it was very clever to see myself on the monitor taking part." Male, age 71(T1)
	"I am not a great fan of computer games but I enjoyed what I did today." Male, age (T1)
	"I would say, I enjoyed the session very much." Female, age 73 (T2)
	"It was a good happy experience and I enjoy it more as it goes along each week." Female, age 85 (T3)
	"Stimulating, good fun and energetic. Really good." Female, age 60 (T3)
	"I thought it was good fun and entertaining. I found the differences between the games interesting!" Female, age 60 (T4)
	"I've really had a good time. I've also enjoyed seeing myself on the telly! Can't beat that!" Female, age 50 (T5)
	"Most enjoyable. Found it beneficial for knees. Shame it had to come to an end." Male, 69 (T6)
	"Is this the last time? I've really enjoyed all the sessions." Female 50 (T6)

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
No (slightly frustrating, baffling)	"Just when you think it is straightforward, things happen to make you realise it is rather harder than you imagined." Male, age 58 (T2) "Found it more frustrating. This session as I expected to better than 1st session." Female, age 61(T2) "Still baffling - especially the volleyball today." Male, age 72 (T4) "Anticipation gives way to powers of observation, and speed of reaction." Male, age 58 (T5)
Mentally challenging	
Yes (needs to concentrate)	"Very enjoyable but needed a lot of concentration." Female, age 70 (T1) "Good work out for concentration." Female, 69 (T2) "I found that I had to concentrate harder and I feel warmer after completing the exercises." Male, age 71 (T3) "Felt I had to concentrate more this time and felt I didn't do so well but found it enjoyable." Female, age 68 (T4) "Very enjoyable finding it easier but must concentrate all the time." Female, age 70 (T4)
No (little effort needed, easy)	"It really doesn't get you thinking and get your brain working." Female, age 73 (T1) "The exercises seemed a little easier this time." Male, age 71 (T2)
Physically challenging	
Yes	"Its been hard work in the old knees.." Male, age 69 (T1) "It was good and fun very physical." Female, age 50 (T2) "..I feel warmer after completing the exercises." Male, age 71 (T3) "...I didn't realize how much effort I had put into each game until each game was over." Female, age 61 (T4) "...it made me work harder.." Female, age 64 (T4)

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
	“Can feel that I have exercised especially in legs.” Female, age 70 (T6) “As the levels increased the level of extra effort required was obvious.” Male, age 64 (T6)
No	“you try automatically to do the exercise.." Female, age 64 (T6) “did not feel I was doing any form of physical activity because I was concentrating mental on the movements I needed to make to complete each game.” " Female, age 61 (T1)
Loss of time consciousness	
Yes (time passed by very quickly)	“Although still as enjoyable, again time passed quickly.” Female, age 61 (T6) “Has it already been six sessions? Doesn’t feel like it!” Female, age 60 (T6)
No	Not available
Self improvement	
Yes (getting better, more skilful, more confident)	“I enjoyed it and as the programme progressed I felt more confident.” Female, age 85 (T1)
	“This was an improvement on my first session. I am starting to get the hang of how the system works.” Female, age 69 (T2) “Using the system a second time felt more confident.” Male, age 64 (T2) “This week I did just a little better than the last time.” Female, age 85 (T2) “Probably more ‘fun’ since familiarity with games and process greater.” Male, age (T2) “Feeling of being able to predict progress of each game higher - but, of course, not always correctly.” Male, age 72 (T5) “Feel I am getting more in tune with exercises.” Female, 61 (T5) “I think I did a lot better on my last lesson.” Female, age 76 (T6)

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
	"Today was good. After a slow start I got into it. I notice, the more I like a certain game, the better score I get - the ones I dislike or feel frustrated with, the worse I perform. A bit like life really!" Female, age 85 (T6)
No (getting worse or none)	"Found it more frustrating. This session as I expected to better than 1st session." Female, age 61 (T2) "my co-ordination on some tasks is not as good as I hope to achieve." Female, age 50 (T3) "Well my coordination wasn't as good this week." Female, age 54 (T5) "I felt my coordination was not so good which made it more difficult." Female, age 68 (T6)
Feeling of ease	
Yes (relaxed, no strain)	"I found it easy to accept the physical challenges and 'threats' of the games." Male, 72. T1 "...excellent form of exercise do not realize how much effort you are using to complete each task." Female, age 61 (T3) "I didn't feel tired at all. Games seem to be easier." Female, age 64 (T3) "We have a good time and laugh a lot and are relaxed and happy." Female, age 85 (T4) "Enjoyed this morning as it seemed more relaxing. Either I'm getting better or not concentrating on the score." Female, age 61 (T4) "...felt good at the end of the session. A sense of accomplishing a task." Female, age 64. (T5)
No (muscles aching, tiring)	"one of my arms ached from what I had been doing, which showed me I was doing more exercise than I thought with the virtual reality." Female, age 54 (T4)
Adapting to VR	

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
Yes (adjusting to the spatial perspective, working out ways to win)	"I enjoyed trying out, in a different way, some of the games I have seen children playing on games machines. I found I had to concentrate hard to adjust to the spatial perspective on the screen. The hardest game in that respect was the volleyball, as I found it difficult to tell if I was heading for the ball, or would be on one side or the other of it. I will be interested to see how well I 'adapt' after a few sessions." Female, age 54 (T1) "Skate boarding always wanted to do that. Swimming can't swim but it was realistic." Female, age 54 (T1) "I am starting to get the hang of how the system works." Female, age 69 (T2) "I'm having more fun as the sessions go by – but I am definitely going to kill the 'ROBOT'! Female, age 85 (T5) "Mentally stimulating to try to beat the robot and miss obstacles in snowboard, grand prix and shark/eel games." Female, age 65 (T6)
No	"Mentally challenging getting familiarized with characteristics of avatar movement on screen - different in each game. " Male, age 72 (T1) "Frustrating." Male, age 69 (T2)
Limitations of the exergaming technology	
Yes (noticed the lapse in motion capture)	" I question – at present – the accuracy of some of the physical/pixel movement of my actual movement" Male, age 72 (T1) "slightly frustrated when the camera did not seem to pick up my outstretched hand..." Female, age 54 (T2) "Whether the problems are due to the computer generation of the images or my inability to adapt remains to be seen.." Male, age 58 (T2) "Sometimes I don't seem to get the reaction from the screen that I thought I have performed." Female, age 69 (T4) "..I do find it frustrating when my actions are not picked up by the camera." Female, age 54 (T4)

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
	“The volleyball - it does not seem to be consistent in the way the ‘hit’ pushes the ball. Some times my ‘hit’ seems ahead if the ball and sometimes behind. It’s difficult for me to judge what the result of my hit will be. I tend to get nearer the front of the green when I play, so that might be affecting the angles on the game 2. The snowboard does not keep up with the speed of sideways movement i.e. I may lean out of the way but the board on the screen is slower, so it hits the obstacles.” Female, age 54 (T5) “The program seemed out of sync on occasions.” Male, age 71 (T6) “In the snowboarding the screen took a while to catch up with my movement, so there was a time delay.” Female, age 54 (T6) “Time lapse on some movements irritating. Otherwise OK.” Male, age 58 (T6)
No	Not available
Perceived benefits of exergaming	
Psychological and/or physical benefit	“...I thought it was great and would be helpful to people ie. with M.S. or arthritis. As it would build your coordination and muscle control.” Female, age 63 (T1) “Hopefully will help with severe back pain given right activity." Female, age 50 (T1) “Great value to the body.." Female, age 50 (T1) “I think that it would benefit people of all walks of life.” Female, age 54 (T2) “I expect this would help people in the future." Female, age 50 (T3) “"I would imagine people with some physical disability would find this form of exercise very appealing." Female, age 72 (T5) “It will have a wide variety of uses and can be programmed to suit different standards of ability." Female, age 69 (T6) “Could be an aid to getting fit and maintaining fitness." Male, age 64 (T6)

Table E.1: Excerpts from responses to the open-ended evaluation

Theme & subtheme	Statement
	“Found it beneficial for knees." Male, age 69 (T6)
Beneficial for indoor use	“...more exciting than your ordinary exercises that you do in a gym." Female, age 50 (T1)
Behavioural intention to use	
Yes (would recommend/use)	“"...I could do this all day." Male, age 69 (T1)
	“I think the session was very good. I would tell a friend about it." Female, age 73 (T1)
	“...good and fun very physical which gives you the incentive to come back.” Female, age 50 (T2)
	“I would like to do a lot more.” Female, age 69 (T3)
	“I really enjoyed this week’s session would advice all my friend about it." Female, age 69 (T5)
	“I would absolutely recommend this form of exercise." Female, age 50 (T6)
No (not likely to use in future)	“Given a choice between computer games or group activities, I would prefer group activities." Male, age 64 (T1)
	“I am still not a great fan of computer games." Male, age 64 (T3)

Appendix F

Correlations between the modified Technology Acceptance model variables

Tables F.1 to F.7 present correlations between the modified Technology Acceptance model. At every time point, BI correlated significantly with PE, EE and SI. Most of the time, there was a negative correlation between BI and age, and there was only a significant association at T3, T4 and T6. There was also strong correlations between the independent variables and the interaction terms. For example, at T0, SI was highly associated with SI x GDR (r = .84, p (two-tailed) $< .001$). The results also showed strong correlations between the interaction terms; i.e. at T5, PE x AGE correlated significantly with EE x AGE (r = .97, p (two-tailed) $< .001$), suggesting the presence of multicollinearity (Aguinis, 1995; Blalock, 1963).

Table F.1: Correlations between BI and predictors at T0

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.72***	.51**	.68***	.05	.27	.55**	.53**	.48**	-.17	.06	-.07	-.07
PE			.65***	.71***	-.08	.26	.72***	.74***	.68***	.14	.09	-.07	-.04
EE				.55**	.05	.03	.76***	.83***	.62***	.10	.003	.18	.07
SI					-.02	.03	.70***	.62***	.84***	-.09	.23	-.11	-.16
AGE						-.17	-.05	.07	-.15	-.26	-.22	.38*	.77***
GDR							-.15	-.02	-.01	.001	.07	-.21	.10
PE X GDR								.66***	.72***	.01	.20	.06	-.05
EE X GDR									.55**	.23	-.09	.20	.06
SI X GDR										.07	.25	-.10	-.02
PE X AGE											.37*	.51**	-.002
EE X AGE												.32	-.19
SI X AGE													.37*
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.2: Correlations between the modified Technology Acceptance model variables at T1

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.80***	.56**	.69***	-.14	.20	.25	.36*	.31	-.27	.21	.02	-.33*
PE			.70***	.77***	-.01	.30	.38*	.56**	.49**	-.26	-.002	-.06	-.11
EE				.62***	-.29	.18	.57**	.68***	.57**	-.002	.07	.08	-.21
SI					-.06	.004	.51**	.58**	.68**	-.06	.09	-.09	-.17
AGE						-.17	-.12	-.21	-.17	-.07	-.14	.07	.77***
GDR							-.18	-.10	-.002	-.18	-.08	-.22	.10
PE X GDR								.70***	.80***	.15	.12	.01	.03
EE X GDR									.63***	.02	-.19	.02	-.27
SI X GDR										-.01	.01	-.22	-.06
PE X AGE											.56**	.60***	.25
EE X AGE												.50**	-.01
SI X AGE													.07
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.3: Correlations between the modified Technology Acceptance model variables at T2

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.84***	.57**	.62***	-.27	.39*	-.05	.26	.08	-.06	.01	-.14	-.33*
PE			.74***	.61***	-.26	.54**	-.14	.11	-.05	-.04	.01	-.12	-.25
EE				.65***	-.43*	.24	.12	.21	.27	.01	.04	-.13	-.31
SI					-.13	.21	-.05	.27	.54**	-.12	-.12	-.38*	-.23
AGE						-.17	-.26	-.31	-.23	.04	.05	-.01	.77***
GDR							-.35*	-.14	-.12	-.12	-.07	-.22	.10
PE X GDR								.74***	.60***	-.09	-.20	.04	-.22
EE X GDR									.64***	-.36*	-.49**	-.31	-.42*
SI X GDR										.02	-.23	-.24	-.11
PE X AGE											.82***	.79***	.35*
EE X AGE												.84***	.16
SI X AGE													.16
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.4: Correlations between the modified Technology Acceptance model variables at T3

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.81***	.64***	.48**	-.35*	.41*	-.11	-.06	.09	.08	.06	.06	-.34*
PE			.80***	.63***	-.16	.51**	-.08	-.004	.20	.08	.19	.01	-.13
EE				.56**	-.33*	.39*	-.01	.12	.20	.18	.28	-.03	-.09
SI					-.13	.09	.22	.21	.71***	.004	-.03	-.16	-.15
AGE						-.17	-.14	-.09	-.15	.13	.35*	.12	.77***
GDR							-.32*	-.24	-.05	-.05	.16	-.11	.10
PE X GDR								.78***	.66***	-.10	-.39*	-.12	-.12
EE X GDR									.57**	-.47**	-.50**	-.30	-.31
SI X GDR										-.15	-.30	-.32*	-.12
PE X AGE											.72***	.73***	.48**
EE X AGE												.60***	.60***
SI X AGE													.18
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.5: Correlations between the modified Technology Acceptance model variables at T4

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.88***	.77***	.48**	-.40*	.35*	.05	.30	.18	.05	.25	.18	-.40*
PE			.68***	.54**	-.32	.44	-.04	.10	.17	-.01	.00	-.06	-.31
EE				.64***	-.57**	.23	.10	.62***	.37*	-.002	.55*	.44*	-.57**
SI					-.35*	.06	.18	.38*	.78***	-.09	.32	.12	-.44*
AGE						-.17	-.33	-.58**	-.43*	.02	-.34*	-.27	.77***
GDR							-.27	-.14	-.03	-.19	-.17	-.23	.10
PE X GDR								.67***	.56**	-.10	.07	.07	-.29
EE X GDR									.64***	-.03	.58**	.50**	-.56**
SI X GDR										-.03	.33*	.13	-.34*
PE X AGE											.45**	.52**	.3*
EE X AGE												.94***	-.28
SI X AGE													-.26
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.6: Correlations between the modified Technology Acceptance model variables at T5

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.82***	.70***	.46**	-.25	.50**	-.13	-.02	-.06	.20	.20	-.07	-.19
PE			.91***	.61***	-.45**	.40*	.16	.24	.17	.21	.20	-.04	-.36*
EE				.54**	-.39*	.19	.25	.37*	.18	.21	.23	-.02	-.31
SI					-.14	.18	.18	.18	.69***	-.03	-.01	-.33*	-.17
AGE						-.17	-.38*	-.31	-.17	-.07	-.02	.18	.77***
GDR							-.24	-.11	-.10	-.12	-.10	-.14	.10
PE X GDR								.92***	.60***	-.11	-.10	-.16	-.44*
EE X GDR									.53**	-.15	-.14	-.23	-.37
SI X GDR										-.10	-.14	-.37*	-.12
PE X AGE											.97***	.75***	.09
EE X AGE												.77***	.05
SI X AGE													.31
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.7: Correlations between the modified Technology Acceptance model variables at T6

	BI	PE	EE	SI	AGE	GDR	PE X GDR	EE X GDR	SI X GDR	PE X AGE	EE X AGE	SI X AGE	AGE X GDR
BI		.94***	.77***	.44**	-.37*	.43*	-.09	.31	.08	.16	.04	.07	-.40*
PE			.83***	.55**	-.35*	.46**	-.05	.34*	.19	.12	-.07	-.01	-.31
EE				.57**	-.39*	.11	.37*	.68***	.36*	-.06	-.08	-.11	-.46**
SI					-.15	.08	.20	.36*	.82***	-.01	-.09	-.31	-.21
AGE						-.17	-.34*	-.46**	-.21	-.04	.47	.06	.77***
GDR							-.29	-.07	-.05	-.15	.32*	-.20	.10
PE X GDR								.86***	.57**	-.14	.001	-.04	-.32*
EE X GDR									.57**	-.13	-.10	-.14	-.38*
SI X GDR										.06	-.11	-.35*	-.14
PE X AGE											.87***	.78***	.22
EE X AGE												.81***	.11
SI X AGE													.11
AGE X GDR													

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

F.1 Correlations between variables in model 2

Tables F.8 to F.13 present correlations between the modified Technology Acceptance model. At every time point, there was a positive association between the previous BI, PE, EE and SI, and the dependent variable BI. There was also strong correlations between the main effects. For example, at T3, PE and EE correlated significantly (r = .80, p (two-tailed) $<$ .001. At T6, there was a strong positive correlation between the previous BI and PE (r = .90, p (two-tailed) $<$ .001). The results showed the presence of conditions indicating multicollinearity.

Table F.8: Correlations between BI and predictors in model 2 at T1

	BI	BI at T0	PE	EE	SI	AGE	GDR	BI X GDR	BI X AGE
BI		.69***	.80***	.56**	.69***	-.14	.20	.16	-.43*
BI at T0			.74***	.57**	.76***	.05	.27	.49**	-.15
PE				.70***	.77***	-.01	.30	.25	-.24
EE					.62***	-.29	.18	.33*	.01
SI						-.06	.004	.52**	-.20
AGE							-.17	-.07	.32*
GDR								-.16	-.15
BI X GDR									.07
BI X AGE									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.9: Correlations between BI and predictors in model 2 at T2

	BI	BI at T1	PE	EE	SI	AGE	GDR	BI X GDR	BI X AGE
BI		.71***	.84***	.57**	.62***	-.27	.39*	.06	-.04
BI at T1			.59**	.39*	.48**	-.14	.20	.34*	.02
PE				.74***	.61***	-.26	.54**	-.14	-.07
EE					.65***	-.43*	.24	.13	.03
SI						-.13	.21	-.01	-.12
AGE							-.17	-.33*	-.32
GDR								-.12	-.27
BI X GDR									.18
BI X AGE									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.10: Correlations between BI and predictors in model 2 at T3

	BI	BI at T2	PE	EE	SI	AGE	GDR	BI X GDR	BI X AGE
BI		.90***	.81***	.64***	.48**	-.35*	.41*	.18	.13
BI at T2			.80***	.56**	.49**	-.27	-.39*	.22	-.01
PE				.80***	.63***	-.16	.51**	-.05	-.06
EE					.56**	-.33*	.39*	.04	-.02
SI						-.13	.09	.18	-.05
AGE							-.17	-.35*	-.24
GDR								-.23	-.19
BI X GDR									.16
BI X AGE									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.11: Correlations between BI and predictors in model 2 at T4

	BI	BI at T3	PE	EE	SI	AGE	GDR	BI X GDR	BI X AGE
BI		.86***	.88***	.77***	.48**	-.40*	.35*	.18	.22
BI at T3			.76***	.80***	.46**	-.35*	.41*	.20	.31
PE				.68***	.54**	-.32	.44*	-.10	.01
EE					.64***	-.57**	.23	.36*	.44**
SI						-.35*	.06	.16	.23
AGE							-.17	-.36*	-.31
GDR								-.25	-.13
BI X GDR									.24
BI X AGE									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.12: Correlations between BI and predictors in model 2 at T5

	BI	BI at T4	PE	EE	SI	AGE	GDR	BI X GDR	BI X AGE
BI		.88***	.82***	.70***	.46**	-.25	.50**	.13	.08
BI at T4			.76***	.58**	.39*	-.40*	.35*	.33*	.21
PE				.91***	.61***	-.45**	.40*	.12	.15
EE					.54**	-.39*	.19	.20	.10
SI						-.14	.18	.04	-.10
AGE							-.17	-.42*	-.25
GDR								-.21	-.18
BI X GDR									.18
BI X AGE									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.13: Correlations between BI and predictors in model 2 at T6

	BI	BI at T1	PE	EE	SI	AGE	GDR	BI X GDR	BI X AGE
BI		.85***	.94***	.77***	.44**	-.37*	.43*	-.05	.14
BI at T5			.90***	.76***	.38*	-.25	.50**	-.08	.14
PE				.83***	.55**	-.35*	.46**	-.10	.12
EE					.57**	-.39*	.11	.26	-.04
SI						-.15	.08	.05	-.02
AGE							-.17	-.20	-.19
GDR								-.32	-.05
BI X GDR									-.16
BI X AGE									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

F.2 Correlations between BI and predictors in model 3

Coefficients of correlations between the variables in model 3 are presented in tables F.14 to F.19. Overall, a high positive correlation was found between BI and PE ($r > .80$ at all time points). The explanatory predictors were also found to have high correlations among them (e.g. at T1, between SI and PE, r = .77, p (two-tailed) $<$ .001; at T2, between PE and EE, r = .74, p (two-tailed) $<$ .001; at T3, between BI at T2 and EE, r = .80, p (two-tailed) $<$ .001; and at T4, between EE and AGE, r = -.57, p (two-tailed) $<$ .01). This was suggestive of multicollinearity caused by predictor intercorrelation in moderated multiple regression (Aguinis, 1995).

Table F.14: Correlations between BI and predictors in model 3 at T1

	BI	BI at T0	PE	EE	SI	AGE	GDR
BI		.69***	.80***	.56**	.69***	-.14	20
BI at T0			.74***	.57**	.76***	.05	.27
PE				.70***	.77***	-.01	.30
EE					.62***	-.29	.18
SI						-.06	.004
AGE							-.17
GDR							

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.15: Correlations between BI and predictors in model 3 at T2

	BI	BI at T0	BI at T1	PE	EE	SI	AGE	GDR
BI		.49**	.71***	.84***	.57**	.62***	-.27	.39*
BI at T0			.69***	.47**	.26	.49**	.05	.27
BI at T1				.59**	.39*	.48**	-.14	.20
PE					.74***	.61***	-.26	.54**
EE						.65	-.43*	.24
SI							-.13	.21
AGE								-.17
GDR								

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.16: Correlations between BI and predictors in model 3 at T3

	BI	BI at T0	BI at T1	BI at T2	PE	EE	SI	AGE	GDR
BI		.48**	.79***	.90***	.81***	.64***	.48**	-.35*	.41*
BI at T0			.69***	.49**	.60***	.47**	.43*	.05	.27
BI at T1				.71***	.59**	.38*	.28	-.14	.20
BI at T2					.80***	.56**	.49**	-.27	.39
PE						.80***	.63***	-.16	.51**
EE							.56**	-.33*	.39*
SI								-.13	.09
AGE									-.17
GDR									

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.17: Correlations between BI and predictors in model 3 at T4

	BI	BI at T0	BI at T1	BI at T2	BI at T3	PE	EE	SI	AGE	GDR
BI		.50**	.65***	.85***	.86***	.88***	.77***	.48**	-.40*	.35*
BI at T0			.69***	.49**	.48**	.58**	.33*	.31	.05	.27
BI at T1				.71***	.79***	.57**	.65***	.32*	-.14	.20
BI at T2					.90***	.81***	.78***	.48**	-.27	.39*
BI at T3						.76***	.80***	.46**	-.35*	.41*
PE							.68***	.54**	-.32	.44*
EE								.64***	-.57**	.23
SI									-.35*	.06
AGE										-.17
GDR										

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.18: Correlations between BI and predictors in model 3 at T5

	BI	BI at T0	BI at T1	BI at T2	BI at T3	BI at T4	PE	EE	SI	AGE	GDR
BI		.48**	.67***	.84***	.90***	.88***	.82***	.70***	.46**	-.25	.50**
BI at T0			.69***	.49**	.48**	.50**	.48**	.37*	.45**	.05	.27
BI at T1				.71***	.79***	.65***	.65***	.59***	.34*	-.14	.20
BI at T2					.90***	.85***	.70***	.54**	.47**	-.27	.39*
BI at T3						.86***	.77***	.62***	.41*	-.35*	.41*
BI at T4							.76***	.58**	.39*	-.40*	.35*
PE								.91***	.61***	-.45***	.40*
EE									.54**	-.39*	.19
SI										-.14	.18
AGE											-.17
GDR											

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.19: Correlations between BI and predictors in model 3 at T6

	BI	BI at T0	BI at T1	BI at T2	BI at T3	BI at T4	BI at T5	PE	EE	SI	AGE	GDR
BI		.50**	.66***	.88***	.87***	.91***	.85***	.94***	.77***	.44**	-.37*	.43*
BI at T0			.69***	.49**	.48**	.50**	.48**	.54**	.51**	.36*	.05	.27
BI at T1				.71***	.79***	.65***	.67***	.58**	.54**	.20	-.14	.20
BI at T2					.90***	.85***	.84***	.82***	.71***	.44**	-.27	-.39*
BI at T3						.86***	.90***	.83***	.69***	.37*	-.35*	.41*
BI at T4							.88***	.90***	.81***	.41*	-.40*	.35*
BI at T5								.90***	.76***	.38*	-.25	.50**
PE									.83***	.55**	-.35*	.46**
EE										.57**	-.39*	.11
SI											-.15	.08
AGE												-.17
GDR												

*,**,*** indicates significance at the 90%, 95% and 99% level, respectively.

Table F.20: VIF values for the modified Technology Acceptance model

VIF	Initial (T0)		T1		T2		T3		T4		T5		T6	
	D only	D+1	D only	D+1	D only	D+1	D only	D+1	D only	D+1	D only	D+1	D only	D+1
PE	2.97	9.94	4.21	6.35	3.43	17.37	4.31	69.13	2.43	10.87	9.77	24.53	6.00	37.51
EE	1.86	19.46	2.41	3.43	3.34	6.78	3.26	108.70	2.99	84.73	6.93	19.04	4.97	25.69
SI	2.17	33.60	3.00	5.28	1.94	20.85	1.92	11.53	1.83	81.16	1.69	10.36	1.55	17.09
AGE	1.04	22.93	1.25	8.28	1.33	20.45	1.19	137.84	1.62	22.04	1.33	9.89	1.22	8.56
GDR	1.18	8.41	1.36	2.52	1.69	9.29	1.56	15.41	1.32	3.33	1.49	5.62	1.88	6.40
PE X GDR		10.14		6.03		11.39		61.28		7.41		14.85		13.27
EE X GDR		19.77		6.38		6.64		101.66		75.44		12.72		14.13
SI X GDR		34.48		4.83		23.76		12.87		80.33		11.38		17.50
PE X AGE		3.42		5.56		21.39		10.25		6.22		53.77		21.65
EE X AGE		2.68		3.11		19.06		5.52		24.42		54.53		17.29
SI X AGE		3.36		2.60		7.83		6.32		22.07		5.59		5.82
AGE X GDR		22.73		10.26		24.39		128.55		27.17		12.62		10.04
Average	1.84	15.91	2.45	5.39	2.35	15.77	2.45	55.76	2.04	37.10	4.24	19.58	3.12	16.25

Greyed out cells are not applicable for the specific column.

Table F.21: VIF values for Model 2

VIF	T1			T2			T3			T4			T5			T6		
	D	D+1	D+2	D	D+1	D+2	D	D+1	D+2	D	D+1	D+2	D	D+1	D+2	D	D+1	D+2
BI at T0	1.00	3.14	3.57															
BI at T1				1.00	1.71	2.98												
BI at T2							1.00	3.40	4.26									
BI at T3										1.00	4.26	4.87						
BI at T4													1.00	2.93	4.21			
BI at T5																1.00	6.69	7.22
PE		4.28	5.15		4.44	7.08		8.54	10.07		2.90	4.64		16.28	22.96		9.11	11.24
EE		2.44	3.06		3.53	4.36		3.71	3.80		5.10	6.30		8.30	10.69		5.62	9.25
SI		4.07	4.47		2.05	2.15		1.92	2.09		1.91	1.91		1.75	1.95		1.73	1.73
AGE		1.33	1.73		1.34	1.64		1.36	1.55		1.59	1.72		1.33	1.76		1.30	1.51
GDR		1.53	1.59		1.66	1.93		1.57	1.74		1.39	1.61		1.52	1.78		2.10	2.60
BI X GDR			1.79			2.21			1.65			1.93			2.01			1.66
BI X AGE			1.53			1.30			1.15			1.78			1.31			1.44
Ave	1.00	2.80	2.86	1.00	2.46	3.94	1.00	3.42	3.29	1.00	2.86	3.10	1.00	5.35	5.83	1.00	4.43	4.58

Greyed out cells are not applicable for the specific column.

Table F.22: VIF values for Model 3

VIF	T1		T2		T3		T4		T5		T6	
	D only	D+1	D only	D+1	D only	D+1	D only	D+1	D only	D+1	D only	D+1
BI at T0	1.00	3.14	1.92	2.27	1.92	2.73	2.02	3.13	2.17	3.02	2.19	3.66
BI at T1			1.92	2.53	2.90	3.56	4.01	5.67	4.24	5.76	4.34	5.99
BI at T2					2.00	4.53	5.69	7.60	6.19	7.19	6.19	7.31
BI at T3							7.69	9.65	9.72	11.22	12.63	15.85
BI at T4									4.71	6.71	5.77	9.59
BI at T5											6.98	15.98
PE		4.28		4.44		8.87		4.27		16.87		11.98
EE		2.44		3.56		3.80		6.07		8.53		7.44
SI		4.07		2.21		2.14		2.06		2.28		2.01
AGE		1.33		1.38		1.45		1.92		1.57		2.21
GDR		1.53		1.71		1.69		1.50		1.79		3.01
Average	1.00	2.80	1.92	2.59	2.27	3.60	4.85	4.65	5.41	6.49	6.35	7.73

Greyed out cells are not applicable for the specific column.

Table F.23: F-values of residuals: Modified Technology Acceptance model

Between	Block 1 $F_{22,22}$	Block 2 $F_{15,15}$
T0 – T6	3.22*	3.28*
T0 – T1	0.78	0.91
T1 – T2	1.53	1.86
T2 – T3	0.51	0.44
T3 – T4	1.80	2.00
T4 – T5	0.64	0.70
T5 – T6	3.12*	4.97***

*p <.05. **p <.01. ***p <.001.

Table F.24: F-values of residuals: model 2

Between	Block1 $F_{26,26}$	Block 2 $F_{21,21}$	Block 3 $F_{19,19}$
T1 – T6	1.61	2.65*	2.21†
T1 – T2	1.15	1.71	1.44
T2 – T3	1.64	0.82	0.88
T3 – T4	0.72	1.25	1.36
T4 – T5	1.32	1.35	1.14
T5 – T6	0.90	1.12	1.13

†: p = 0.05
p <.05. **p <.01. ***p <.001.

Table F.25: F-values of residuals: model 3

Between	Block 1	Block 2
T1 – T6	$F_{26,21}$ = 2.83*	$F_{21,16}$ = 4.97***
T1 – T2	$F_{26,25}$ = 1.10	$F_{21,20}$ = 1.68
T2 – T3	$F_{25,24}$ = 2.21*	$F_{20,19}$ = 1.51
T3 – T4	$F_{24,23}$ = 0.59	$F_{19,18}$ = 0.60
T4 – T5	$F_{23,22}$ = 1.61	$F_{18,17}$ = 1.99
T5 – T6	$F_{22,21}$ = 1.22	$F_{17,16}$ = 1.63

†: p = 0.05
p <.05. **p <.01. ***p <.001.

Appendix G

Study 2: Information

G.1 Letter of Approval for study 092/10

Teesside University
Middlesbrough Tees Valley
TS1 3BA UK
www.tees.ac.uk

Teesside University

PRIVATE AND CONFIDENTIAL

Direct Line: 01642 384124

20 September 2010

Prof Denis Martin
School of Health & Social Care
Teesside University

Dear Denis

Study No 092/10: The effects of virtual-reality-augmented exercise in older people with self-reported chronic musculoskeletal pain.

Decision: Approved

Thank you for submitting an amended application pack. I am pleased to confirm that the comments raised by the School of Health & Social Care Research Governance and Ethics Committee have been addressed in your amended application pack and your study has been approved through Chair's Action. Your study may proceed as it was described in your approved application pack.

Please note:

Where applicable, your study may only proceed when you have also received written approval from any other ethical committee (e.g. NRES) and operational / management structures relevant (e.g. Local NHS R&D). A copy of this approval letter **must** be attached to applications to any other ethical committee. If applicable please forward to me a copy of the approval letter from NRES before proceeding with the study.

In all cases, should you wish to make any substantial amendment to the protocol detailed, or supporting documentation included, in your approved application pack (other than those required as urgent safety measures) you must obtain written approval for those, from myself and all other relevant bodies, prior to implementing any amendment. Details of any changes made as urgent safety measures must be provided in writing to myself and all other relevant bodies as soon as possible after the relevant event; the study should not continue until written approval for those changes has been obtained from myself and all other relevant bodies.
On behalf of the School of Health & Social Care Research Governance and Ethics Committee please accept my best wishes for success in completing your study.

Yours sincerely

Dr. Alasdair MacSween
Chair
Research Governance and Ethics Committee
School of Health & Social Care

G.2 Study 2: Recruitment pamphlet

Title of study: The effects of virtual-reality-augmented-exercise in older people with self-reported chronic musculoskeletal pain

- **Are you aged 65 or over?**
- **Are you able to walk without using any aids like a stick or Zimmer?**
- **Do you have musculoskeletal pain in your body which has lasted more than 12 weeks?**
- **Are you free from any injury or condition which would prevent you taking exercise?**

If your answers to questions above are YES, then would you please read on and consider taking part in a research project conducted as part of my PhD studies into exercise and virtual rehabilitation for older people?

I want to investigate how people like you feel about undertaking a six-week exercise programme and some of those who agree to take part will be asked to do six weeks of twice weekly exercise sessions supervised by me and some will do the same thing but with a virtual reality exercise system called IREX^{TM}. The IREX^{TM} system is similar to TV weather forecasts where the forecaster is shown standing in front of and interacting with, a changing weather map. Both types of exercise sessions do not involve difficult or strenuous physical movements.

If you decide to take part you would be asked to attend the Teesside Centre for Rehabilitations Sciences at James Cook University Hospital or the Therapy Lab at

Teesside University twice weekly over the course of six weeks either for a series of standard exercise sessions or exercise sessions using the IREX^{TM}.

This research has been approved by the School of Health & Social Care Research Governance and Ethics Committee and NRES.

If you are interested, please contact me for further information.

Yvonne Khoo Telephone: 01642 384697 Email : H8085063@tees.ac.uk

G.3 Study 2: Reply slip

If you are interested in taking part or would like to ask any questions of me or my supervisor, please print your name here –

By post – please tell me the address and what time/hour(s) of dayÐ

By phone – please tell me the number and what time/hour(s) of day Ð

By email – please tell me your email address –

Please post this reply slip to me at:

Yvonne Khoo

Middesbrough Tower (Health Phoenix 2.09)

Teesside University

Borough Road

TS1 3BA.

Or email me at H8085063@tees.ac.uk Telephone number: 01642 384697

G.4 Study 2: Participant information sheet (PIS)

Title of study: The effects of virtual-reality-augmented-exercise in older people with self-reported chronic musculoskeletal pain

Researcher: Ms Yvonne Khoo

Supervisor: Prof Denis Martin

Study identification Number 092/10

Purpose of the Study

My name is Yvonne Khoo and I am a Full Time PhD student in the School of Health and Social Care at Teesside University. As part of my PhD I am investigating how virtual-reality-augmented exercise may affect balance and postural stability in older people with self-reported chronic pain. The study also aims to understand how older people relate to the virtual environment and how they think and feel about doing exercise using a type of virtual reality technology. The virtual reality system I am using is called the IREX^{TM} (Interactive Rehabilitation Exercise System).

Before you decide whether or not to participate please read this Information Sheet and if you have any questions please do not hesitate to ask me or my supervisor.

Why have I been invited to consider participating?

You have been invited because you meet certain conditions called inclusion criteria and don't have other things called exclusion criteria. This means that you must be: 65 years or older, able to walk without any help or aids (for half a mile at least) and have had musculoskeletal pain in two or more joints, for example your knees or shoulder, and/or your lower back, for 12 weeks or more.

Unfortunately if you are not able to use written and spoken English you would not be able to take part. Also if you have: already taken part in my previous research study, fallen at any time in the last 12 months, been diagnosed with dementia, or have any systemic conditions that may cause you pain in areas of your body (for example in your joints such as your knee) for 12 weeks or longer (things like cancer, rheumatic or neurological diseases etc), have ever been told by a physician or health professional that you should avoid exercise, or if you are allergic to alcohol wipes, shaving cream, or hypoallergenic adhesive tape you cannot take part.

What would I be asked to do it I decided to take part?

You would be asked to attend either the Teesside Centre for Rehabilitations Sciences at James Cook University Hospital or the Therapy Lab in the Constantine Building at Teesside University twice a week for a period of six weeks for a supervised 30 minute exercise session. Every effort will be made to arrange the dates and times when you attend to suit your schedule, within normal working hours. If you agree I will also let your GP know you are taking part.

At each session you will either be asked to perform standard exercises or play five virtual reality games using the IREX™ system. I will give you written instructions (a copy is attached) telling you exactly what is involved in each type of exercise. I will also demonstrate all the exercises you will be asked to try before you begin. You will only begin each session when you are both confident that you know what you are supposed to do and are happy to try. If you experience any discomfort during the session at all you should stop immediately – these are not difficult or strenuous exercise and you should be comfortable at all times or you should stop.

At the beginning and the end of the study you will be asked to fill in one questionnaire about the virtual reality exercise session and two questionnaires in relation to your general health and function. After every session you will also be asked to fill in one questionnaire about how you felt about the session and I will ask you a few questions about how hard you felt the exercises were.

Before you begin I will measure your balance and muscle activity; for this you will be asked to complete a short walk–100 m–as a warm up. Following this, small pads will be placed on your lower leg muscles to measure your muscle activity. You will be asked to sit in a special chair where you will be asked to press your foot – by moving your ankle up and down and side to side, five times, at a comfortable pace. During this your leg will be comfortably secured to the chair by a padded strap which helps to make sure you only move your ankle and not you knee. Following this I would ask you to stand on a special plate on the ground (with support bars for you to hold, if necessary) and look straight ahead at a dot on the wall and stand still for ten seconds with your eyes open and then again for ten seconds with your eyes closed. I would then help you to take off the pads and put on a small belt around your chest and a wristwatch which records your heart rate. This belt fits under your clothes and you would be asked to wear this during all exercise sessions.

Half of the people (chosen by chance) who take part will then be asked to do some standard exercises which are described in full in the sheet attached and I will teach and supervise you at all times. The other half will be asked to play some IREX^{TM}

games where they stand in front of a green cloth and see themselves on a TV screen again these are described in detail on the attached sheet. IREX^{TM} games are not like virtual reality games you may have seen, or played, in arcades where you actually sit in a car, or stand on a snowboard, with IREX^{TM} you just stand on the floor and move and your image is projected on the TV into the game and the images are controlled by your movements. None of your movements need to be fast or big - you move only as much, or as little as you wish to, and you are always standing on level ground in all games, in your own shoes. There is no other equipment involved and no images of you are ever recorded.

What are the possible benefits of taking part in the study?

The study has not been designed to give benefits to the people who take part and so you should not expect any. The type of exercise you would do, however, are known to provide benefits to balance, muscle control, and improve mental faculties where physical-mental coordination is concerned.

What are the possible risks involved in taking part in the study?

We do not think there are any risks for healthy people like you other than the risks that are involved with any physical exercise. The exercises involved are not strenuous, large and fast movements are not required and at all times you will exercise at your own pace and move only as much and as quickly as you wish to. The exercises are always carried out with both feet on a level surface and no equipment is involved in the exercises other than the IREX^{TM} system.

Expenses and Payments

As this study is being undertaken as part of my PhD studentship I am sorry but I will not be able to give you any payment or reimburse any expenses you have.

What happens if something goes wrong?

This study is covered by the University's Insurance Policies. If you believe that you have been harmed in any way by taking part in this study, you have the right to pursue a complaint. We would advise that you contact the Assistant Dean for Research in the School, Prof. Janet Shucksmith (J.Shucksmith@tees.ac.uk) in the first instance if you should have any complaints about the study.

Who has reviewed this study?

This project has been reviewed and approved by the School of Health & Social Care Research Governance and Ethics Committee and the National Research Ethics Service.

Can I withdraw from the study if I change my mind?

Yes you can stop at any time you wish to without giving any reason and none of your rights will be affected. If you would like to withdraw after data has been collected you can do so at any point up until 16th January 2011. If you choose to withdraw your data after it is collected you do not need to give any reason and none of your rights will be affected. If you would be willing to tell us why you wanted to stop though that would be helpful for us in understanding your experience of the study. To withdraw quote your unique study identity number (which I have written on the top right hand corner of this sheet) to my Director of Studies, Prof. Denis Martin (whose contact details are at the end of this sheet) and your data will be removed and destroyed.

Confidentiality, Anonymity and Data Storage

All information collected during this study will be stored in accordance with the Data Protection Act (1998). Your Consent Form will be stored in a locked filing cabinet housed in my Director of Studies' office in the Parkside West Offices, Teesside University (TU). Data will stored in a format where it is linked to you by a code number until 16th Jan 2010 after which that link will be destroyed and it will be fully anonymous. Hard copies of the data will be kept in a locked filing cabinet in my office in the Phoenix building, TU. Electronic files will be kept on a password protected server at TU. Data will be held securely for 20 years and will not be used for any purpose other than as described here unless it is for another research project which an appropriate research ethics committee has approved.

Access to the study materials and data will be restricted to members of the research team: myself and Prof. Denis Martin, Prof. Paul van Schaik, Dr Alasdair MacSween and Dr John Dixon who are all full time members of staff at TU.

How will the data be used?

The results of this study will be included in my PhD thesis, publications in peer reviewed journals and conference presentations. While the results may include a direct quote of something you said in answering a question - which you may recognise yourself if you read it - at no time will your identity or any other identifiable information be revealed unless required by law.

Thank you for taking the time to read this information sheet.

If you have any questions please feel free to contact me :

Yvonne Khoo J-Lyn

01642 384697

Email: H8085063@tees.ac.uk

or my Director of Studies:

Prof. Denis Martin, DPhil.

Parkside West Offices,

University of Teesside

01642 382754 Email: d.martin@tees.ac.uk

G.4.1 Exercise instruction sheet: Experimental group

Dear participant,

You will be invited to play a series of five games in each session. Please remember at no time will you ever need to perform strenuous exercises, you will never do any running or jumping, or strenuous activity involved. All you do is simple movements within comfortable range, repeated at your own pace taking rests whenever you wish to. The image you will see on the screen may make some big or dramatic movements as you move but you don't! You can do the exercises in your usual clothes and footwear as long as your shoes don't have raised heels. The exercises are always carried out with both feet on a stable level surface so there is minimal risk of slips or trips.

You will be asked to do each game five times in each session.

1. Volleyball

You will see a simulated beach setting with a robot opponent standing opposite you.

Figure G.1: The virtual beach environment of the IREX^{TM} volleyball application

What to do:

Land the ball in your opponent's court or outside your court!

How to play:

Either move your body, shoulder or touch the volleyball by hand.

Tip:

Smoother movements allow better contact with the ball!

2. Sharkbait

You will see yourself virtually deep-sea diving with sea creatures! You don't even have to wear any diving gear!

Figure G.2: The virtual sea environment of the IREX^{TM} Sharkbait application

What to do:

Catch as many stars as you can!

How to play:

Lean side-by-side, crouch down or raising your arms.

To move sideways quickly, step to the side.

Remember that if you meet a shark, it will virtually swallow you and expel you out of its mouth. Contact with an electric eel virtually temporarily disable your movement.

Tip:

When you have got the hang of *navigating*, the deep sea is all yours!

3. Formula Racing

You will see yourself virtually driving in a Grand Prix. The course of the track is also visible to you.

Figure G.3: The virtual IREX^{TM} formula racing application

What to do:

Drive through the racecourse as best as you can!

How to play:

Steer by stepping to the right or left, by moving your body to the side, or by moving one arm at a time.

Tip:

If you feel that you haven't moved on the track, take one small step to the side to move your car!

4. Snowboarding

You will see a red silhouette of yourself standing on a snowboard, coming down a narrow slope, and a virtual image of yourself when you cross the finish line.

Figure G.4: The virtual beach IREX^{TM} snowboarding application

What to do:

Make as many jumps as possible and avoid hitting other objects.

How to play:

Begin by stepping sideways until you are centred over the snowboard.

Lean to either side, or move your arm to one side.

Tip:

A good centred position on the snowboard allows easier navigation.

5. Birds and Balls

You will virtually be in a pastoral background with colourful balls coming at you.

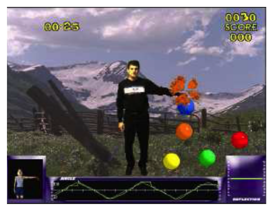

Figure G.5: The virtual IREX^{TM} birds and balls application

What to do:

Turn as many balls into birds as you can.

How to play:

Touch the balls with any part of your body eg. once you have exercised with your right shoulder or arm, you may repeat it with the left.

Tip:

The balls will not pop if they are approached with a gentle touch.

Thank You for Your Participation

G.4.2 Exercise information sheet: Control group

Dear participant,

You will be invited to perform standard exercises. All the exercises will be guided and demonstrated. Participants will not at any point be asked to perform strenuous exercises, there is never any running or jumping, or strenuous activity involved; the exercises are simple movements which are performed only within comfortable range and repeated at the participants own pace taking rests whenever they wish to. Participants can do the exercises in their usual clothes and footwear as long as their shoes do not have raised heels. The exercises are always carried out with both feet on a stable level surface so there is minimal risk of slips or trips.

There will be five types of exercises that involve:

1. Physical movement of the upper extremities and balance

Stand up straight with knees slightly bent and your feet shoulder width apart. Clasp both hands in front of your abdomen and slowly raise both arms to the front until eye level, and lower both arms. Repeat 3 times.

Following this, stand comfortably with both arms by your sides. Raise the right arm away from your body until shoulder level and then lower it down again to your side. Repeat with the left arm.

Following this, move two steps to the right and repeat the movement of the arms; repeat with movement to the left.

2. Full body movement with bending and stretching

Stand up straight with knees slightly bent and your feet at a comfortable width apart. Stretch out both arms so that they form a T with your body and slowly bend your knees to a comfortable position. Keep your back straight, while in this position, transfer your weight to the right leg and reach out to the right side with your upper torso and right arm as much as you can. Hold for 2 seconds and gently move your position back as you were before you reached to the right. Repeat with the left side.

(Take regular short breaks if needed)

Repeat with body bending forward. Take short steps in between.

3. Trunk mobility, movement of the upper torso and balance

Stand up straight with knees slightly bent and your feet shoulder width apart. Gently hold both hands in front of your torso with both elbows bent. Look straight ahead while maintaining a relaxed stance, and gently turn your body to the right and back to original position, then to the left and back to original position.

Repeat the same this time with your arms extended.

4. Full body movement, working on pelvic tilt and hamstrings

Stand up straight with your feet shoulder width apart. Place your hands in front of your body as if to hold an imaginary ball and look straight ahead. Move your pelvis to the front (towards your hands) and hold for 2 to 3 seconds, and to the back. Repeat as many times as you can.

Next stand upright and take a comfortable step forward with your right foot (almost into a lunge position). Rest your hands on your hips and gently tilt your body to the right and back to where you started. Repeat this by standing upright again, this time with a step forward with your left foot, resting your hands on your hips and gently tilting your body to the left, and back to where you started. Try to keep your upper body upright and your back as straight as possible.

5. Shoulder rotation, fine motor exercise and upper extremities

Stand up straight with your feet shoulder width apart. Place both arms at your sides. Beginning with the right arm: slowly move your right arm upwards until shoulder level and gently open and close your right hand (this involves movement of the thumb, fingers and palm). Repeat with your left arm. As you progress through the sessions, use both arms at different positions (e.g. to the top of your head, stretching to the top left or right).

Thank You for Your Participation

G.5 Study 2: Consent form

1. I confirm that I have read and understand the Participant Information Sheet (Version 1, dated 27th August 2010) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that the data collected during the study will not have my name on it and no information will be released or printed that would identify me unless required by law. ☐
3. I understand that the data relating to me will be kept confidential and only those members of the study team named on the information sheet, who need to see it, in order to complete the study, will be allowed to see it. ☐
4. I agree to the electronic data files being kept on a Teesside University server and other documents being held in locked filing cabinets in Teesside University for 20 years. ☐
5. I am aware that I have the right to withdraw at any point until 16th January 2011. ☐
6. I confirm that I meet the inclusion criteria and do not have any of the exclusion criteria as stated on the information sheet for this study. ☐
7. I agree that the data collected on me may be used for future research only if an appropriate ethics committee has approved that research. ☐
8. I understand that relevant sections of the data collected during the study may be looked at by individuals from regulatory authorities and/or from the James Cook University Hospital where it is relevant to my taking part in this research. I give permission for these individuals to have access to this data. ☐
9. I agree to take part in the study named on the other side of this form. ☐

____________________	____________________	____________________
Name of participant	Date	Signature

____________________	____________________	____________________
Name of researcher	Date	Signature

G.6 Study 2: Demographic data collection form

PARTICIPANT Unique study number:	
Age in years:	
Gender:	
Height (m):	
Weight (kg):	

G.7 Study 2: Recording form for musculoskeletal pain

Please indicate your average pain in each location (listed below) in the last month on a scale of 0–10, with 10 being the worst possible pain:

Location of pain	**Score (0–10)**
Hands/wrists	
Foot	
Back	
Chest	
Other – please detail	

Please indicate your average pain in your hips/knees in the last month, during the following activities, on a scale of 0–10, with 10 being the worst possible pain.

Pain in Hips/Knees when:	**Score (0–10)**
Walking on a flat surface	
Walking on stairs	
Lying in bed at night	
Sitting or lying down during the day	
Standing upright	
Other – please detail	

Please indicate the pain you are feeling at the moment, in each location (listed below), on a scale of 0–10, with 10 being the worst possible pain.

Location of pain	**Score (0–10)**
Hands/wrists	
Foot	
Back	
Chest	
Hips/knees	
Other – please detail	

Appendix H

Pain prevalence

Table H.1: Frequency of participants' self-reported chronic pain by location experienced within 30 days at the start and end of the intervention (N = 54)

	Control		Experimental	
Location of pain	Start	End	Start	End
Hands/wrists	17	17	10	11
Foot	11	12	13	10
Back	20	18	14	13
Chest	4	4	1	4
Knees	4	1	4	2
Hip	13	13	14	14
Neck	1	0	2	5
Shoulder	5	3	4	6
Leg	0	0	2	1
Groin	1	1	0	0
Ankle	0	0	1	0
Head	0	0	1	1

Table H.2: Frequency of participants' self-reported chronic pain occurrence at the start and end of the intervention (N = 54)

	Control		Experimental	
Location of pain	Start	End	Start	End
Hands/wrists	9	6	7	9
Foot	8	8	8	4
Back	13	15	13	11
Chest	4	1	0	2
Knees	0	0	5	4
Hip	13	10	14	11
Neck	0	0	1	2
Shoulder	2	1	5	5
Leg	0	1	0	0
Groin	0	1	0	0
Ankle	1	0	0	1
Head	0	0	1	0

Table H.3: Frequency of participants' self-reported chronic pain experienced during various activities within 30 days prior to testing at the start and upon completion of the intervention (N = 54)

	Control		Experimental	
Location of pain	Start	End	Start	End
Walking on a flat surface	19	16	18	15
Walking on stairs	19	19	18	17
Lying in bed at night	19	21	18	13
Sitting or lying down during the day	18	13	12	13
Standing upright	17	18	15	11
Pain in the foot while walking	1	0	0	0
Prolonged standing	0	0	0	1
Kneeling	1	1	0	0
Getting out of bed in the morning	1	1	0	1
Changing direction of physical movement	1	1	0	1

Table H.4: Frequency of pain groups classified following Leveille et. al 2002

Class	Control n = 27	Experimental n = 27
1	1	1
2	5	10
3	5	5
4	16	11

Table H.5: Differences in pain occurrence by McNemar's chi squared test with Newcombe's correction (N = 54)

	Control			Experimental		
	χ^2	*p*	95% CI of the difference	χ^2	*p*	95% CI of the difference
Hands/wrists	1.29	0.26	[-9.01, 30.24]	2.00	0.16	[-20.00, 5.08]
Foot	0.00	1.00	[-21.00, 21.00]	4.00	0.046	[-0.82, 30.85]
Back	1.00	0.32	[-21.99, 7.96]	0.50	0.48	[-13.88, 27.15]
Chest	3.00	0.08	[4.42, 28.44]	19.59	0.00	[26.19, 56.21]
Knees				0.11	0.74	[18.47, 25.48]
Hip	1.80	0.18	[-5.77, 26.80]	1.29	0.26	[-8.47, 29.22]
Neck				1.00	0.31	[-18.97, 10.13]
Shoulder	1.00	0.32	[-10.13, 18.97]			

Note. Not included: leg, groin, ankle, head. Greyed cells are not applicable for the specific column.

Appendix I

Conference abstracts and poster presentations

57th Annual Meeting & 1st World Congress on Exercise is Medicine®

June 1–5, 2010

Baltimore Convention Center

Baltimore, Maryland

Acceptance and experience of virtual-reality-enhanced exercise in older people

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Keywords: virtual reality, exercise, older people, technology acceptance

BACKGROUND AND PURPOSE: Virtual reality (VR) has produced new opportunities for physical activity[1−4] and exercise augmented by VR has become popular in younger people. For older people the health and quality of life benefits

arising from exercise are well documented[15–7] but how older people would react to VR-augmented exercise remains under researched. Key questions around how older people may engage with VR technology, interact with VR environments and feel about their experience are likely to be important factors determining their concordance with VR-augmented exercise programmes. Two constructs from the psychology of human-computer interaction lend themselves to research in this new field of VR exercise for older people.

The first is technology acceptance and use, embodied in the Unified Theory of Acceptance and Use of Technology (UTAUT)[8] . This model comprises six dimensions: performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitation conditions (FC), self efficacy (SE) and behavioural intentions (BI). BI, specifically focuses on a personÕs self-reported likelihood to continue to use a technology to which they have been recently introduced. The second construct is flow state[9], a psychological state in which people act with total involvement (akin to athletes descriptions of being in the zone); and comprises nine dimensions: enjoyment (ENJY), clear goals (GOAL), challenge-skill-balance (CHAL), concentration (CONC), paradox of control (CONT), unambiguous feedback (FDBK), action-awareness-merging (ACT), transformation of time (TRAN) and loss of self-consciousness (LOSS).

The aim of this study was to investigate how older people perceive and experience VR-augmented exercise, with a specific focus on their self-reported likelihood of future use.

METHOD

Design: Longitudinal cohort study.

Sample: 28 healthy men and women aged 50 years and above (mean 65.2, SD 7.79, range 50-85) who currently participated in community-exercise and were able to walk unaided. Exclusion criteria: medical conditions contraindicating exercise, receiving recent rehabilitation for a medical condition and any doubt of ability to give Informed Consent.

Setting: A UK University Laboratory.

Intervention: Upon giving written Informed Consent, participants took part in a total of six exercise sessions, over three weeks, using IREX^{TM} - a VR system that uses participantsÕ body movements and gestures to control their image projected in a VR Environment in real time[6]. Each session lasted approximately 40 minutes and involved five interactive IREX^{TM} games, each of which was repeated three times per session.

Measurements: Technology acceptance and use was measured by way of the Modified Technology Acceptance Questionnaire[8] (each dimension produces a score from 1-7, where 7 indicates the highest degree of acceptance). Other measures were flow state using the Flow Questionnaire[9] (each dimension produces a score from 1-5, where 5 indicates the highest degree of flow); perceived effort via the Borg Perceived Rate of Exertion Scale[11]; mental effort via the Subjective Mental Effort Questionnaire (SMEQ)[12]; and an open question at the end of each exercise session - What did you think of the session?

Analysis: The primary outcome was change in Behavioural Intention (BI) over the course of the programme. Change in BI was analysed by calculating, from a repeated measures one-way ANOVA, the 95% confidence interval of the difference before and after the three week programme. Secondary analysis investigated change over time for the other technology acceptance and flow state dimensions using separate repeated measures one-way ANOVAs. Planned comparisons from these tests calculated mean differences and their 95% confidence intervals. The planned comparisons for each of the technology acceptance dimensions between before and after the programme. For each of the flow dimensions the planned comparisons were between the first and last exercise session.

RESULTS: BI increased after the programme (mean difference 0.99, 95% confidence interval 0.41, 1.58, effect size 0.65). This was from a baseline mean of 4.70 (SD 1.26). Based on a minimally important change of 0.63 this represents a high chance (88.8%) that the true value of the change in BI is substantially positive. (There is an 11.2% chance that the change is trivial, and a 0% chance that the effect is negative.)

A beneficial effect was found for the other acceptance measures: PE (chances of true value being positive 98.6%, trivial 1.4%, negative 0%), and EE (chances of true value being positive 100%, trivial 0%, negative 0%), SI (chances of true value being positive 69.7%, trivial 30.3%, negative 0%), FC (chances of true value being positive 99.9%, trivial 0.1%, negative 0%), and SE (chances of true value being positive 99.7%, trivial 0.3%, negative 0%). The following dimensions of flow showed at least possible substantial improvements too: ENJY (chances of true value being positive 69.4%, trivial 30.6%, negative 0%), GOAL (chances of true value being positive 97.8%, trivial

2.2%, negative 0%), FDBK (chances of true value being positive 50%, trivial 50%, negative 0%) and LOSS (chances of true value being positive 99.8%, trivial 0.2%, negative 0%). For the other flow dimensions the changes were most likely to be trivial. There was no evidence of a negative effect. Physical effort, by way of the Borg Scale, showed a highly likely increase (chances of true value being positive 86.6%, trivial 11.7%, negative 1.7%); whereas any change in mental effort (SMEQ) was most likely to be trivial (chances of true value being positive 11.8%, trivial 85.3%, negative 2.9%).

CONCLUSION: Overall participants reported their experience of VR enhanced exercise to be positive. While not all measured dimensions improved or changed with the intervention and time there was no evidence of the quality of the experience decreasing. These results suggest that VR-augmented exercise is likely to be received well by older people. They support an expectation that older people from this population, after using VR technology for exercise, are very likely to use it in the future which may aid concordance with therapeutic exercise programmes.

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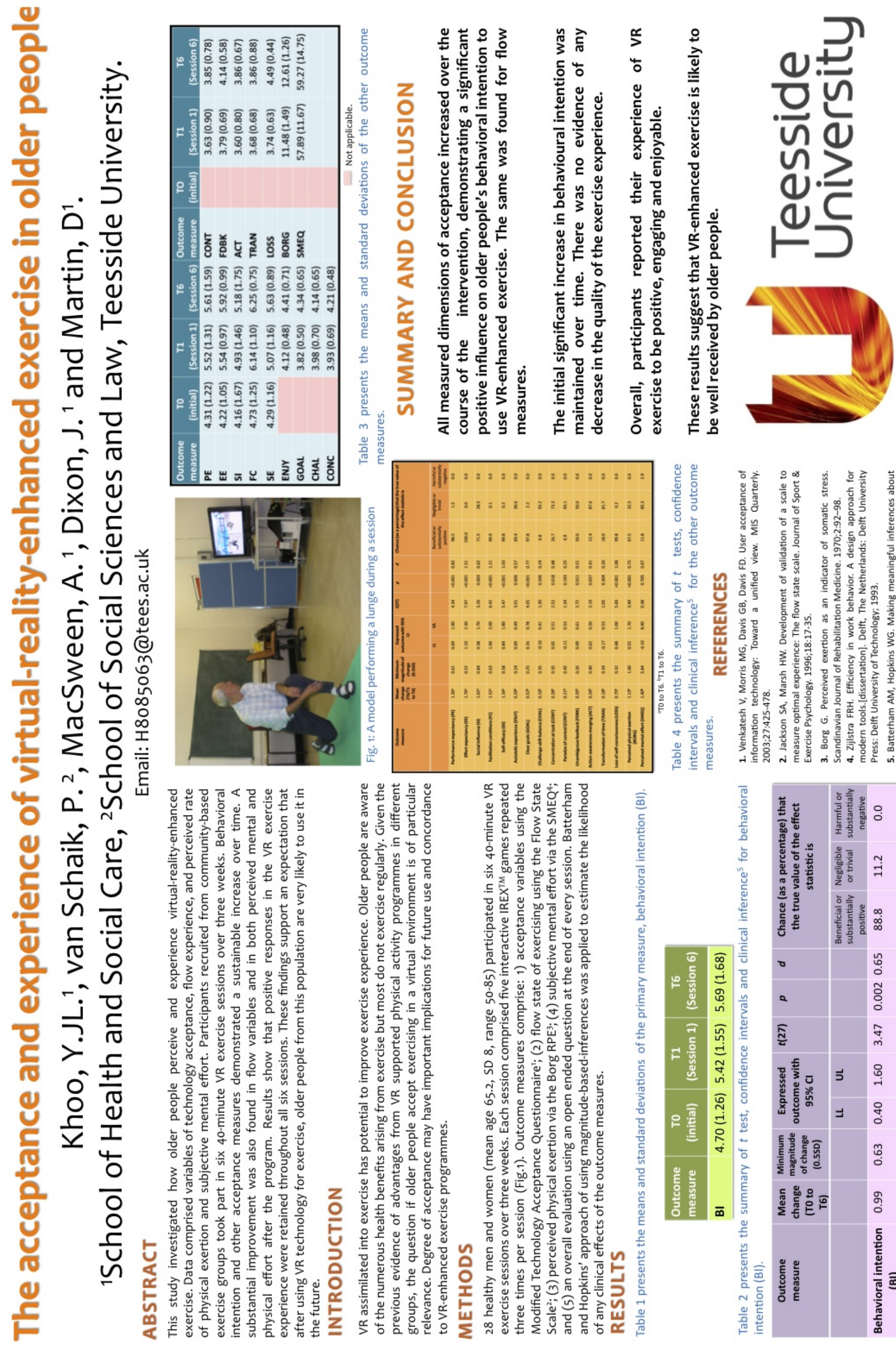

Figure I.1: Poster presented at the ACSM 57th Annual Meeting, Baltimore USA, June 2010

North East Postgraduate Conference (NEPG)

Friday, 23rd October 2009

Lindisfarne Room,

Kings Road Centre, Newcastle University.

The acceptance and experience of virtual-reality-enhanced exercise in older people

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INTRODUCTION

Virtual-reality (VR) has great potential for use in rehabilitation and exercise contexts[1−4]. Older people who exercise are generally healthier, more independent and enjoy a better quality of life compared to their sedentary peers. Given the previous evidence of advantages from VR supported physical activity programmes in different groups, the question if older people accept exercising in a virtual environment is of particular relevance.

Degree of acceptance may have important implications for future use and concordance to VR-enhanced exercise programmes. Therefore, this study investigates how older people perceive and experience virtual-reality-enhanced exercise.

METHOD

Participants will take part in a six 40 minute exercise sessions over a three week period using the IREX^{TM} VR system.
(1) acceptance variables using the Modified Technology Acceptance Questionnaire[5]; (2) flow state of exercising with the IREX^{TM} using the Flow Questionnaire[6]; (3) physical effort via the Borg Perceived Rate of Exertion Scale[7]; (4) mental effort via the Subjective Mental Effort Questionnaire (SMEQ)[8]; and (5) an overall evaluation using an open-ended question at the end of each exercise session. Statistical analysis will comprise regression, repeated measures one-way ANOVA and moderator analysis.

DISCUSSION AND CONCLUSION

The findings of this study will help us to understand:

- the extent to which VR-enhanced exercise is accepted by older people,
- describe acceptance and experience before and after the programme, and throughout the six sessions, and
- identify any possible demographic explanatory factors.

The results may have important implications for exercise promotion strategies for older people.

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Figure I.2: Poster presented at the North East Postgraduate Conference, Newcastle University, 2009

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