THE EFFECTS OF EXERGAMING VERSUS MIRROR MATCHED GYM BASED

EXERCISE WITH NO VIRTUAL STIMULI ON TECHNOLOGY ACCEPTANCE, FLOW AND

POSTURAL CONTROL IN A HEALTHY YOUNG SUBJECT POPULATION

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DECLARATION:

I declare that this thesis is entirely my own work and represents the results of my own research carried out at Teesside University. I declare that no material within this thesis has been used in any other submission for an academic award.

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Abstract

This thesis investigated the effect of exergaming versus mirror matched gym based exercise with no virtual stimuli on technology acceptance, flow and postural control in healthy young adults. Firstly a review of literature was performed analysing the effects of technology acceptance and flow on exergaming, and the effects of exergaming on postural control. Results showed the plausible nature of exergaming as an immersive environment and the potential to improve postural control. However, some major gaps in the literatures were identified. Technology acceptance had never been applied in exergaming and flow had only partly been applied to exergaming in limited studies. Additionally the effects of exergaming on postural control had shown some potential benefits, however no study had truly analysed the effects of exergaming on postural control by analysing mirror matched exercise with no virtual stimulus. The purpose of this thesis was to address these important areas of research and contribute novel evidence to the field.

In two separate studies, 38 non active and 50 active young healthy adults took part in either exergaming based training or mirror matched gym based exercise with no virtual stimuli. Technology acceptance (behavioural intention), flow and postural control were measured at pre and post exercise intervention.

Technology acceptance results showed that performance expectancy was significantly higher in the exergaming group in both studies, as well as being a significant predictor of behavioural intention at both pre and post exercise testing. In the second study, only, performance expectancy, social influences, and behavioural intention where statistically significantly higher for the exergaming group compared to the mirror matched gym based exercise with no virtual stimuli on technology acceptance, highlighting greater levels of acceptance into the exercise environment. Flow results showed greater levels immersion in the exergaming groups, especially in terms of clear goals, unambiguous feedback, action awareness merging, transformation of time and loss of self- consciousness.

The effects of exergaming on postural control showed significant improvements in anterior-posterior standard deviation and range for the exergaming group in study one, and improvements in medio-lateral range in study two. Study two also showed significant improvement over time (pre-post exercise) for medio-lateral SD, range and centre of pressure.

Evidence from both studies suggests that exergaming may offer an immersive environment for exercise which has a positive effect on behavioural intention to keep using the exergaming system in the future. With regards to postural control evidence from both studies suggest that exergaming may offer a new method of exercise to improve static postural control.

Abbreviations

AE- Autotelic experience

AP- Anterior- posterior

AM- Action-awareness-merging

β- Standardised regression coefficient

BI- Behavioural intention

CB- Challenge-skill balance

CG- Clear goals

CoP- Centre of Pressure

CT- Concentration of task

EE- Effort expectancy

FC- Facilitating conditions

FSS- Flow state scale

LS- Loss of self- consciousness

ML-Medial-lateral

SD- Standard Deviation

SI – Social influences

P- Significance Level

PS2- PlayStation 2

PC- Paradox of control

PE- Performance expectancy

R- Multiple correlation coefficient

R^2 - Squared multiple correlation coefficient

sEMG- Surface electromyography

TAM- Technology acceptance model

TRA- The Theory of Reasoned Action

TPB- Theory of planned behaviour

TT- Transformation of time

UF- Unambiguous feedback

UTAUT- Unified theory of acceptance and use of technology

VR- Virtual reality

Glossary of Terminology

The information in the glossary of terminology refers to frequent use of the terms in the thesis.

Avatars- a virtual image of a body presented in a cartoon format.

Balance/postural stability –"The ability to control the centre of mass in relationship to the base of support" (Shumway-Cook & Woollacott 2007).

Base of support (BOS) - the area of the body that is in contact with the support surface (typically the ground).

Centre of gravity (COG) is the vertical projection of COM onto the ground.

Centre of Mass (COM) "a point that is the centre of the total body mass, which is determined by findings the weighted average of the COM of each body segment" (Shumway-Cook & Woollacott 2007).

Centre of Pressure (CoP) is the point location of the vertical ground reaction force vector. It represents weighted averages of pressures distributed over the surface of the area when feet are in contact with the ground. In order to keep the COM within the base of support this requires the CoP to continuously move around the COM (Shumway-Cook & Woollacott 2007).

Dance Dance Revolution (DDR) an interactive dance based game created by Konami. DDR aims to get people moving on a dance mat to different music, using forward and backwards and side to side arrows.

Exergaming – a combination of exercise and computer gaming for example Nintendo Wii™ or the XBOX Kinect™ ™ as an example of a commercial product.

Flow – a state in which an individual can become totally immersed within an activity, in the thesis flow state flow state will be assessed using a flow state scale questionnaire which comprises of a 36 item questionnaire

Maximal voluntary isometric contractions (MVIC's) – the ability to produce a "voluntarily maximal effort during an isometric contraction for a given muscle group" (Soderberg and Knutson, 2000).

Nintendo Wii™- Released in 2006 the Wii is a popular exergame that uses a hand held Wii remote to control the Avatar characters by pointing the remote at the screen.

Rate of Perceived exertion (RPE) – a psychological scale of physical exertion which participants can rate their own levels of exertion, this is a subjective value of exertion.

Postural control- involves controlling the body's position in space for enabling stability and orientation and is active in all positions (supine, sitting, and standing).

Postural sway- Humans sway invariably to maintain balance using small forward and backward (anterior-posterior) and side-to-side (medial-lateral) motions; the magnitude or velocity of which is a measure of balance.

Unified Theory of Technology Acceptance (UTAUT) - a questionnaire designed to assess people's behavioural intention for future use.

Wii-habilitation- the use of the Nintendo Wii as a method of physical therapy used within a rehabilitation setting for a variety of clinical conditions.

XBOX Kinect™ – an interactive exergame which captures body movements in real-time without the need to use worn or handheld controllers, the person's body acts as the controller using gesture recognition.

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1. INTRODUCTION

1.1 Overview

This chapter provides historical background into exergaming and an explanation of the rationale for the research project. Furthermore, the chapter explores the reasons behind why people may use exergames as a means of exercise and concludes with an outline of the organisation of the thesis.

1.2 Background

1.2.1 Introduction

Virtual reality is a relatively new concept that is becoming ever more mainstream in society. An increasingly popular adaptation of virtual reality is its use in exercising - "exergaming". Exergaming involves the use of computer-generated environment with which users interact with to undertake physical exercise. A number of systems are available commercially and have been highly popular with the general public such as the Nintendo Wii™, Sony Eye Toy™, Dance Dance Revolution™, and more recently the XBOX Kinect™. Exergaming offers a novel way to exercise in the comfort of your own home and gives people the opportunity to exercise and gain biofeedback training at the same time, with the use of such as a virtual trainer.

1.2.2 Historical development

There have been a number of landmarks in the development of exergaming. In the 1970's Myron Krueger was an early proponent of video capture technology and used the term artificial reality to describe the idea of an "interactive immersive environment" (Krueger 1991). The 1980's saw further pioneering developments in what was now more commonly termed Virtual Reality (VR) like Jaron Lanier's company Visual Programming Language (VPL) research in 1985. This was one of the first VR-based companies to produce

equipment, described as "goggles and gloves", to enable people to interact with VR environments.

In the late 1980's Exus released the foot craz for the Atari 2600's this was the first dance mat game to be released commercially in 1987. In 1988 Nintendo™ released the Power Pad, an interactive gaming mat which was double sided for game play, one side had a grid with 12 touch circles and the other side had a star shaped grid with 8 circles on it, allowing multiple games to be usually within a single-player mode such as track and field. The games in the 1980's were still very new to the exergaming development, with arcades usually having the games rather than in the home. Effectively the systems were very much played on a social level within an arcade context. In 1998 seen exergaming become more commercially known as a method of entertainment when Konami released Dance Dance Revolution® (DDR) which was based off earlier work of the foot craz. DDR™ is played on an interactive dance mat and players have to move in direction with the visual cues and in time to the music that is played in the background. Typically movements of the feet are forward and backwards or side to side, higher scores are achieved by obtaining movements in rhythm with the music. DDR soon became popular in arcades and also in the home and school environment.

Exergaming took another leap forward in the mid 2000's especially in terms of home based exergaming with the release of the Sony Eye Toy in 2004, they Eye Toy, combined with gesture recognition and a camera built into the eye toy, produced virtual images (avatars) on screen whilst playing. Despite the initial success of the Sony EyeToy selling 2 million copies in Europe in the first year of sales (Sony Website), this was short lived, as the major development in the exergaming genre came in 2006 when the Nintendo Wii® (Nintendo Co. Ltd., Tokyo, Japan) was released, followed quickly by the Wii Fit in 2007, selling 84 million units during its first 4 years of sales (Nintendo Website). Competitors soon followed. The Playstation Move® was released in 2009 which is based on a hand held controller much like the Wii and offers a variety of different exergames.

It was not until 2010 when exergaming revolutionised by the release of the Microsoft XBOX Kinect® which became the first commercial exergame to be played using a hands free method of game play. The Kinect™ is the first exergaming system where the camera captures body movements in real-time without the need to use worn or handheld controllers. The Kinect™ allows for more natural movements to occur during exergaming as opposed to the Wii™ which is based on the hand held controller. The Kinect™ allows for body images to be tracked in real time and has a play back mode in some games (Kinect sports) which can be used as a biofeedback tool. Currently the Kinect™ is the only commercial exergame on the market which does not require and hand held devices and relies solely on body movements of the players to move the avatars, thus encouraging a wider range of movements.

1.2.3   Exergaming for health

Commercial exergaming systems are widely available and relatively affordable and are promoted to the general public as ways of keeping fit and improving health. Exergaming based interfaces are also found in traditional gym equipment such as treadmills and cycle ergometers which use TV monitors to stimulate virtual settings such as cycling the tour de France (Tour de France bike trainer).

Exercise therapy is a major part of rehabilitation for a wide range of health conditions and since the 1990s exergaming has gained a place within physical rehabilitation, (Greenleaf &Tovar, 1994; Kuhlen & Dohle 1995; Sveistrup 2004). Indeed, the use of the Wii fit™ system within rehabilitation gave rise to the term – Wiihabilitation. Essentially, with the adoption of the likes of the Wii™ rehabilitation therapists were taking systems primarily designed for the entertainment market and applying them in a clinical setting.

Another approach to exergaming for rehabilitation was the design of systems with the primary purpose of assisting with rehabilitation. One of the most notable developments within that approach is the Interactive Rehabilitation Exercise System (IREX™). The IREX™

system is an interactive game system which games are specifically designed to be used by people with movement and learning difficulties, and it has been installed within a number of rehabilitation settings (Weiss, Bialik, and Kizony 2003). The IREX™ system uses a 10 foot green screen whereby participants stand in front of a real-time camera and their body image is tracked and recorded. Once the system is calibrated to the person's body image the green screen is eliminated and the persons own body image is super- imposed into a virtual environment. Multiple environments and interactions have been designed that permit the exercise specialist or physical therapist to grade the intensity and difficulty of the movements elicited from the subject. The IREX™ system has gained a wide range of clinical support in primarily neurological conditions such as traumatic brain injury (Sveistrup, McComas, Thornton, Marshall, Finestone, McCormick, Babulic, and Mayhew 2003; Thornton, Marshall, McComas, Finestone, McCormick, & Sveistrup 2005), children with Cerebral Palsy and learning difficulties (Weiss et al., 2003) and stroke (Brown- Rubin, Rand, Kizony, and Weiss 2005). A plausible reason why exergaming has become so popular in society and rehabilitation is that exercising in a virtual environment shifts the focus from the person's efforts to that of interaction with the VR environment and allows enjoyment of a meaningful activity (Reid, 2002). Interestingly, its core foundation, gesture technology, fed directly into the genesis of the Microsoft Xbox Kinect™, which, as noted above, has revolutionised the exergaming industry.

1.3   <u>Why Exergaming?</u>

Exergaming is now an option of choice for exercise and rehabilitation. However, a legitimate question is, outside its obvious cosmetic attraction, what is the point of exergaming over exercise that does not use such technology? Once the novelty wears off what value does exergaming add to exercise and exercise therapy?

The most common arguments for the unique selling point of exergaming are based on the psychology of exercise. Such arguments talk about the motivational possibilities of the virtual

environment and the potential power of the technology to immerse the person in the activity and distract or augment the performer's attention (Grealy, Johnson & Rushton 1999; Keshner, 2004). These are important in ensuring one of the most fundamental and challenging aspects of exercise for health and rehabilitation - concordance. If someone exercises half-heartedly or less frequently than necessary then they are unlikely to reap the benefits.

1.3.1   Flow in Gaming

In order to facilitate continued behaviour to partake in activities such as exergaming people need to feel a sense of enjoyment and motivation to continue with the activity. Previously research has showed that video gaming is a popular choice for a leisure activity, for children, adults and especially adolescents (Lenhart, Madden, & Hitlin, 2005). Within leisure time people spend time doing activities such as exercise, listening to music and playing computer video games (Hoffman & Novak, 2009) because they are intrinsically motivated to do so and get enjoyment out of doing the activities, this can otherwise be known as being in a state of "flow ". Csikszentmihalyi, (1975) described "flow" as a state when people are intrinsically motivated to take part in an activity and perform the tasks automatically purely for their own sake and not for external gratification or reward. The sense of enjoyment through being in "flow" can be associated with repeated performance of the activity and effectively continuing to take part in the activity. Csikszentmihalyi (1990) described flow as;

"A mental state of operation in which a person is fully immersed in what he or she is doing".

Playing video games has previously been linked to flow (Sherry, 2004; Hoffman & Novak, 2009; Weibel, Wissmath, Habegger, Steiner, and Groner 2008; Faiola and Voiskounsky 2007) whether it be during normal gaming or online gaming, both have shown to elicit flow states. According to Csikszentmihalyi (1990) there are nine characteristics which bring about the intrinsic motivation needed for flow; balance between challenge and skill, clear goals, unambiguous feedback, concentration of task, sense of control, action-awareness merging,

transformation of time, loss of self- consciousness, and autotelic experience. The balance between challenge and skill is one of the key contributes to people being in "flow". If the skill levels for the game are too high and complex then people would be less likely to experience flow, likewise if the game is too easy and the player's skill outweigh the game then boredom begins to set in. Within the gaming context, computer games are designed in levels and goals in which the achievement of these have been known as a contributing factor for people to have optimal "flow" (Weber et al. 2009). Sherry (2004) acknowledged the importance of flow in video games ''Video games possess ideal characteristics to create and maintain flow experiences in that the flow experience of video games is brought on when the skill of the player match the difficulty of the game" (Sherry, 2004, p. 328). Jin (2011) concurs with Sherry (2004) and suggests that video games are most likely to induce flow due to: having goals; utilising feedback for the players as an indication of how well they are performing (game scores/levels); having opportunities to challenge peoples skill levels (challenge-skill balance) and uses "multimodal (visual, aural, and haptic)" elements to heightens concentration by screening out distractions.

To date, there has been limited research examining the effects of flow on exergaming, despite the successful application of flow to both video gaming and exercise, separately. Along with motivational aspects of game play the nature of repeating the activity is also critical to understand in exergaming in order to help facilitate concordance.

Within any exercise or rehabilitation program it is essential that people continue with the exercise on a longitudinal basis in order to gain physiological and psychological benefits. However, within exercise, concordance is often a problematic issue to any type of exercise or therapy, in that people fail to attend sessions; the exercise becomes tedious and monotonous and leads to drop- outs. A plausible solution to mundane exercise is the concept of exergaming. Exergaming has shown the potential to be motivating and enjoying, but the larger and unanswered questions still remains in that will people accept this method of exercise and express willingness to continue the exercise on a repeated nature and

ultimately concord to the exercise. A potential theory which helps understand elements of intention to maintain exercise is the Unified Theory of Acceptance and Use of Technology (UTAUT), (Venkatesh, Morris, Davis, & Davis, 2003).

1.4   Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, et al., 2003) provides a conceptual model for analysing usability/acceptance. The UTAUT was designed in order to develop a unified model acceptable for analysing technology acceptance and use in the information technology field. Technology is continuously expanding at rapid rates; however in order for new technologies to be successful it is essential to understand why people would use a new method of technology and why they would continue to use it. Within the UTAUT model people's behavioural intention to use the system is of the primary importance. Behavioural intention to use refers to the intention of someone's to use the system or exercise again; it measures future behavioural intention/usage. By incorporating both flow and UTUAT to exergaming will allow for a more detailed understanding of peoples potential enjoyment and motivation experienced during exergaming as well as peoples ease of use and behavioural intention to use exergaming in the future.

Other arguments take the view that exergaming can provide a somehow better physical training stimulus than other forms of exercise, such as that it uses more functional and co-ordinated movements and allows a relatively easy and reliable way of grading exercise (Sveistrup 2004). A challenge in making comparisons with other forms of exercise is ensuring that there is sufficient match between the different forms to allow the influence of the VR environment to become apparent. For example, recently O'Donovan et al., (2012) analysed energy expenditure between the Wii™ and the Kinect™ and found that the Kinect™ elicited higher energy expenditure. However, in this study only one game was played on each console and the movements in these were quite different.

1.5   <u>Dual Approach</u>

It is important to understand both the psychological and physiological aspects of exergaming in order to gain a wider understanding of the recent phenomenon in exercise trends (exergaming). Both the psychology and physiology of exergaming have previously been researched relatively superficially and separately. Using a dual approach will allow exergaming to be explored in greater depth and potentially explain people's intention to use exergaming as a method of exercise and the motivations behind why they would us it, as well as the physiological response to exergaming compared to traditional exercise.

In the current thesis a healthy young adult population will be used to explore a dual approach of exergaming. Balance was chosen as a physiological measure due to its high importance in respect to active daily living and fundamentally balance is essential to day to day living. Balance training was specifically chosen over other forms of physical functioning (cardiovascular/strength) as in nature balance training alone has been noted to be tedious and repetitive and often leads to lack of interest in performing balance specific exercises, (Vernadakis et al., 2012). The use of exergaming could potentially alleviate the tedious nature of balance training alone, as it uses an interactive environment for people to exercise in. As the application of exergaming is relatively new within balance research a healthy young population was chosen as a baseline measure to see if balance can be improved, and the results can be generated and tailored towards elderly and clinical populations.

In summary, the current thesis aimed to analyse peoples levels of technology acceptance and flow for game play with specific objectives: 1) to assess peoples behavioural intention to use exergames in the future, 2) assess peoples exergaming motivations through the application of flow and 3) analyse whether exergaming can have improve balance over mirror-matched gym based exercise with no virtual stimuli. The thesis will provide vital information regarding people's behavioural intention to use exergaming as a means of exercise and the potential use of exergaming as a means of balance training.

1.6   Thesis Structure

Chapter 2: Literature Review

Chapter two consists of two separate systematic reviews of literature and critical evaluation of studies examining 1) the psychology of exergaming with regards to technology acceptance and immersion) and 2) the effects of exergaming on postural control. Firstly the chapter will explain the background and theoretical underpinning of two psychological theories; the unified theory of acceptance and use of technology model (UTAUT) and flow state scale (FSS) followed by the systematic review. The second part of the chapter will explore a review of literature with regards to balance training and exergaming. The chapter concludes by identifying the questions yet to be answered regarding technology acceptance and immersion (flow) during exergaming compared to mirror-matched exercise, and the effects of exergaming as a method of balance training.

Chapter 3: Review of measurement techniques

Chapter three analyses the reliability of measurement techniques for outcome measures used in both the instrumentation and methodology of both studies in the thesis.

Chapters 4: Study 1

Chapter four provides background information, methodology, results, discussion and conclusion for study 1. A randomised controlled trial of non-active adults acceptance (behavioural intention) and flow experience (absorption in the activity) of exercising in: an exergaming environment (IREX™) or a mirror-matched exercise environment. Including an investigation of the XBUS™ system as a measure of postural control.

Chapter 5: Study 2

Chapter five provides background information, methodology, results, discussion and conclusion for study 2 for healthy active adults. A randomised controlled trial of physically active healthy adults acceptance (behavioural intention), flow experience (absorption in the activity) and postural control (before and after), exercising in: an exergaming environment (XBOX Kinect™) or a mirror-matched exercise.

Chapter 6: Overall discussion

Chapter 6 provides an overview of the main findings from the two studies relating to the effects of exergaming on technology acceptance, flow and postural control in both healthy non active and active adults. General limitations and future research which would provide further valuable contribution to knowledge regarding exergaming and technology acceptance, flow and postural control are highlighted at the end of the chapter.

Chapter 7: Conclusions and Recommendations

Chapter 7 provides overall conclusions of the thesis, including limitations of testing and future work.

2. BACKGROUND LITERATURE

2.1 Introduction

The aim of this chapter is to provide an overview of the unified theory of acceptance and use of technology model (UTAUT) and flow as theoretical frameworks for examining technology acceptance (behavioural intention) and flow of playing exergames. The first part of this chapter will give an overview of the two psychological frameworks (UTAUT and flow) and how they can be applied to exergaming, followed by a systematic review of user- experience and exergaming. In the second part of the chapter the physiological aspects of exergaming; in particular the effects of exergaming on balance and postural control will be discussed. The chapter concludes with the aims of the thesis.

2.2 Models of technology acceptance

The popularity of digital technology has increased rapidly in the Western society over the last decade, with the demands of new technologies such as Apple's iPads/iPhone, online gaming and social networking (Facebook, Twitter) are even more prominent. With the release of new technologies it is important to understand user-acceptance and why people would use and continue to use these technologies. Davis (1993) regards user-acceptance as essential in terms of success or failure of a new information system. The following section will explore acceptance theories and the constructs which make up the theories which explain user - acceptance.

2.3 Models and theories that contribute to the UTAUT

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003) provides a theoretical framework to explain acceptance of technology and usage behaviour towards using an information system (IS). Previous theories have explained variance in intention and acceptance however; it was not until 2003 when the UTAUT was developed which brought together a unified theory of acceptance with specific reference to usage and intention (Venkatesh et al., 2003). The UTAUT incorporates 8

existing models of technology adoption; the theory of reasoned action (TRA) (Ajzen & Fishbein 1975), the theory model of planned behaviour (TPB) (Ajzen, 1991), the technology acceptance model (TAM) (Davis, 1989), the motivational model (MM) (Davis, Bagozzi, & Warshaw, 1992), a model combining the technology acceptance model and the theory of planned behaviour (C-TAM-TPB) (Taylor & Todd, 1995a), the model of PC utilization (MPCU) (Thompson, Higgins, & Howell, 1991), the innovation diffusion theory (IDT) (Tornatzky & Klien, 1982 Moore & Benbasat, 1991;1996), and the social cognitive theory (SCT) (Bandura, 1986; Compeau & Higgins, 1995). The following sections give and outline of the 8 models which contribute to making UTAUT.

2.3.1   The Theory of Reasoned Action (TRA)

The theory of reasoned action (TRA) was developed by Ajzen & Fishbein (1975) (Figure **1**) which offers an explanation for human behaviour from a social psychology perspective. The TRA main construct is to understand the motivational mechanisms responsible for predicting and individuals behaviour. The TRA has three main constructs to help explain intention, those being; attitude, subjective norm, intention which contribute in explaining actual use. Firstly a person needs to have an attitude (whether it be positive or negative) formed from beliefs in order to assist with the intention, along with subjective norms (social influences) formed from normative beliefs. Thus it is believed that and individual's behaviour is a direct result of intention and in turn intention is a result of attitudes and subjective norms.

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┌──────────────────────┐      ┌──────────────────┐
│ Beliefs and Evaluations │─────▶│ Attitude towards │
│                      │      │    behaviour     │
└──────────────────────┘      └──────────────────┘
                                        │
                                        ▼
                                ┌──────────────┐      ┌────────────┐
                                │ Behavioural  │─────▶│   Actual   │
                                │  Intention   │      │  Behaviour │
                                └──────────────┘      └────────────┘
                                        ▲
                                        │
┌──────────────────────┐      ┌──────────────────┐
│ Normative beliefs and │─────▶│ Subjective Norms │
│  motivation to comply │      │                  │
└──────────────────────┘      └──────────────────┘
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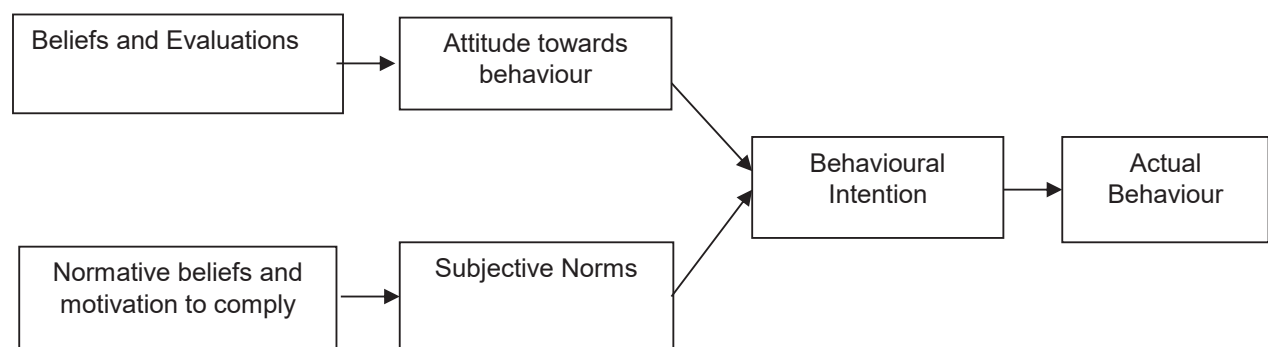
Figure 1: The Theory of Reasoned Action (Ajzen & Fishbein, 1975)

The TRA has previously been use in information technology research to explain behavioural intention and usage (Hsu and Lu 2007). Hsu and Lu (2007) used the TRA to analyse the effects of trust and enjoyment on the intention to play online gaming. A total of 253 gamers took part in the investigation and it was found that trust (behavioural belief) can influence intention indirectly through attitude.

Despite the popularity of TRA in social psychology and information technology to explain behavioural intention and usage, there are some limitations with the model, such as actions that are not thought of in advance are hard to be explained by the model and assumptions that behaviour is under volitional control. An extension of the TRA is the Theory of planned behaviour (TPB) which attempts to explain some of the limitations.

2.3.2   The Theory of Planned Behaviour (TPB)

The theory of planned behaviour (TPB) was later developed by Ajzen (1991) as an extension of the TRA. Both TRA and TPB suggested that the best predictor of behaviour is behavioural intention. TPB analyses behavioural intention in further depths than the TRA in that the model applies perceived behavioural control to help explain both intention and behaviour in greater depths (see Figure **2**). TPB addresses limitations of TRA in dealing with behaviours over which people have incomplete volitional control. In the TPB it is assumed that most human behaviour occur as a result of individuals' intention to perform the behaviour and their ability to make conscious decisions (volitional control) in doing so. The two models differ in respect to the TPB uses perceived behavioural control as a mechanism to explain behavioural intention. Perceived behavioural control refers to an "individual's perceptions relating to the ease or difficulty of performing the behaviour" (Ajzen 1991). The TPB suggests that together with attitude, subjective norms and perceived behavioural control, intention and behaviour can be explained in greater detail. Armitage and Conner (2001) conducted a meta- analysis on the TPB and TRA and the results showed that

the addition of perceived behavioural control significantly explained variance in intention and behaviour and suggested the use of the TPB over the TRA in explaining usage. Özer and Yilmaz (2011) compared the TRA and TPB to explain accountants' information technology usage. A total of 437 accountants completed the TRA and TPB questionnaires regarding IT usage and the results showed that the TPB had higher predictive power to explain IT usage compared to the TRA, thus concurring with earlier work form Armitage and Conner (2001).
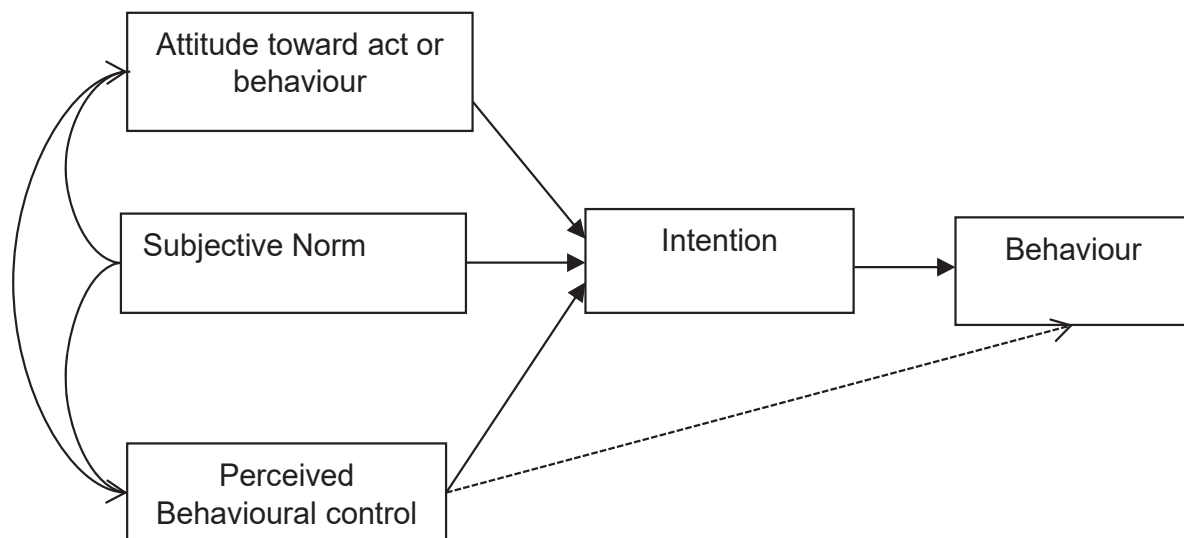
Figure 2: The Theory of Planned Behavior (Ajzen, 1991)

Both the TRA and TPB contribute to the development of the UTUAT through behavioural intention, this is the main dependant variable used in the UTAUT to explain potential usage of a system in the future.

2.3.3 The Technology Acceptance Model

The technology acceptance model (TAM) (Davis, 1989), provides a model to explain technology acceptance, usage and intention to use new technology (see Figure **3**). TAM is an adaptation of theory of reasoned action (Ajzen & Fishbein, 1975) in that beliefs influence attitudes, which lead to intentions and thus producing behaviour. In the TAM an

individual's behavioural intention to use new technology is determined by two main contributors; peoples perceived ease of use (PEOU) in which a person's feels confident to use the technology and free from effort and perceived usefulness (PU) which is the belief in which the persons feels the technology will improve their performance. Davis (1989) stated that these two contributors can be direct predictors of behavioural intention. Other contributors to the TAM are external variables; these can be related to environmental factors which may influence behaviour such as organizational structure (Armenteros et al., 2013); attitude relates to individuals interest in using the system which can have a direct effect on behavioural intention; the belief that an individual will use the system in the future.
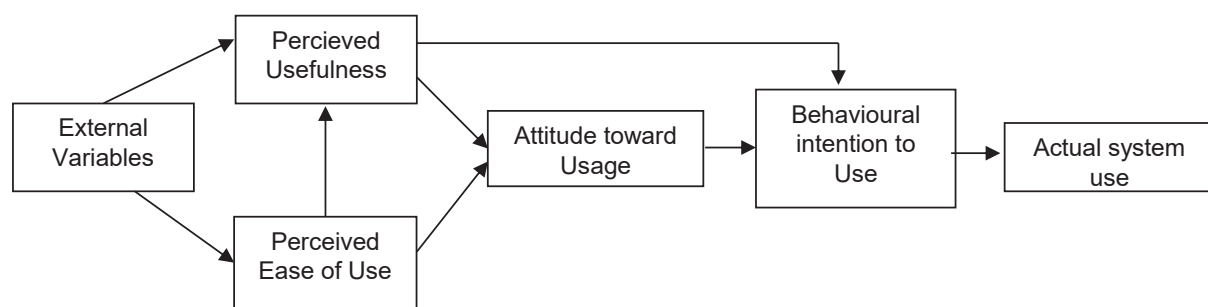
Figure 3: The Technology Acceptance Model (TAM) (Davis, 1989)

It is believed that the TAM is one of the most widely used models to explain technology acceptance in the information technology field (King & He, 2006; Legris, Ingham, & Collerette, 2003) and has been one of the most influential theories to help understand technology acceptance and behavioural intention and is key to the development of UTAUT. Zhang and Mao (2008) used the TAM to explain user acceptance of mobile short messaging service (SMS) advertising in 262 mobile phone users and found that perceived ease of use and perceived usefulness were direct predictors of intention. The results concurred with Davis (1989) who believed that PEOU and PU are direct predictors of intention. King and

He (2006) conducted a meta- analysis on the TAM consisting of 88 published studies, and concluded that the TAM is a robust and valid model, that has been widely accepted for predicting acceptance in information technology in particular. In relation to UTAUT perceived ease of use relates to effort expectancy and perceived usefulness is performance expectancy, the latter of which is believed to the strongest predictor of behavioural intention.

The TAM has limitations in that it does not apply social and control factors on user-behaviour, which have been found to have significant influence on information systems usage behaviour (Mathieson 1991; Moore & Benbasat 1991; Taylor & Todd, 1995b; Thompson et al., 1991).

2.3.4   Combined TAM and TPB (C-TAM-TPB)

In respect to the TAM Taylor and Todd (1995a) combined TAM and TPB to develop (C-TAM-TPB) which incorporates the predictors used in TPB with perceived usefulness used in the TAM (see Figure **4**) in order to gain a wider understanding of the mechanisms needed to fully understand peoples acceptance of technology and behavioural intention to use technology.
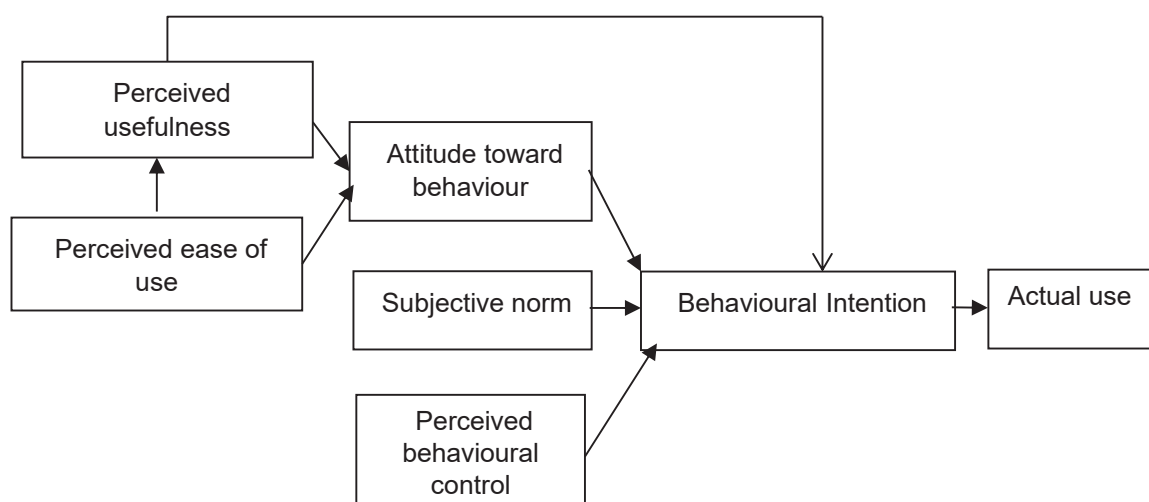
Figure 4: combined TAM and TPB (C-TAM-TPB) (Taylor & Todd, 1995a).

2.3.5   The Model of PC Utilization

Thompson, Higgins, & Howell, (1991) designed the MPCU model to look at usage and intention to predict PC utilization. The MPCU uses concepts of job fit (extent the technology will help their performance), complexity (degree of complexity of technology), long term consequences (effect of long-term use), affects towards use (positive of negative feelings associated with use), social factors (influences from social groups to use technology) and facilitating conditions (provision of support for PC use) to explain PC utilization.

2.3.6   The Motivational Model

The motivational model (MM) (Davis et al., 1992) provides a model relating to intrinsic and extrinsic motivation towards using a system and the perceived benefits that go with the usage. For example people may be more inclined to use a system if they feel it has financial rewards or the opportunity for job promotions in relation to external motivation or people may use the system because they feel it will help them achieve goals and targets for more individual goals. The aspects of enjoyment during gaming have been linked to intrinsic motivation (Pasch et al., 2009; Fitzgerald et al., 2010).

2.3.7   The Innovation Diffusion Theory

The innovation diffusion theory (IDT) (Tornatzky & Klien, 1982; Moore & Benbasat, 1991; 1996), has five main concepts applied to the theory including; relative advantage, compatibility, complexity, and trialability and observability. Relative advantage refers to an innovation or product being perceived as having greater advantages over the product that is being replaced. Compatibility refers to a product being consistent with existing values and

beliefs for the end user. Complexity is the users perception of ease of use of the new innovation, trialability is time in which a new product can be tested for and observability is the ability for the innovation/product success to be viewed by others. The IDT and TAM share similar characteristic in relation to each other, for example relative advantage and perceived usefulness (PU) in the TAM share similar characteristics, likewise complexity construct in IDT relates to the TAM in respect to the complexity of a task and ease of use of the innovation/equipment is one of the most important aspects of technology acceptance and more importantly behavioural intention and usage.

2.3.8   The Social Cognitive Theory

The social cognitive theory (SCT) (Bandura, 1986; Compeau & Higgins, 1995) is one of the most well established theories in psychology for explaining human behaviour. The SCT largely takes environmental factors into account when explaining behaviour. Bandura (1986 1986) believes that human behaviour is described as an interaction of personal factors, behaviour, and the environment. The SCT has three core interactions, the interaction between the person and behaviour involves the person's thoughts and actions. The second interaction is between the person and the environment involves human beliefs and cognitive competencies that are developed and modified by social influences and the environment. The third interaction, between the environment and behaviour, involves a person's behaviour determining the aspects of their environment and in turn their behaviour is modified by that environment. Within the SCT self- efficacy is a major concept applied to motivation and behaviour.

2.4   Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al (2003) describe three basic concepts illustrated in Figure 5 that are key to technology acceptance. Firstly, an individual must have a positive reaction using the new technology in order to develop a level of intention to use the technology which will in course produce actual use of the new technology. In turn, the actual use of the technology will relay back to the individuals initial reaction to the technology. Intention, in particular behavioral intention is core to the UTAUT model in order to predict future intention and acceptance of a new technology/equipment.
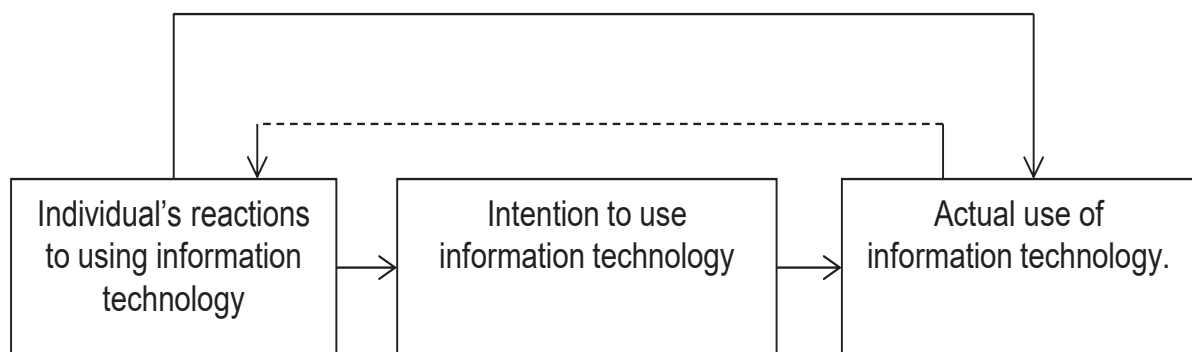
Figure 5: High-level representation of technology acceptance (Venkatesh et al., 2003)

UTAUT has four direct determinants of behavioural intention and actual usage; *performance expectancy, effort expectancy, social influences, and facilitating conditions.* Additionally, there are four variables which are believed to moderate the impact of the four main constructs on behavioural intention and usage*; age, gender, experience* and *voluntariness of use,* (Venkatesh et al., 2003*),* However, attitude towards using the technology, self-efficacy and anxiety are believed not to be direct determinants or moderators of behavioural intention. (see Figure 6). Other models such as the technology acceptance model have been reported to explain variance in intention from 33% (Plouffe et al., 2001) to 52% Taylor and Todd (1995b) and the theory of reasoned action accounting for 26-32% of variance

explained in intention (Davis et al., 1989); therefore UTAUT was used in the current thesis as it offers a robust measure of technology acceptance and behavioural intention.
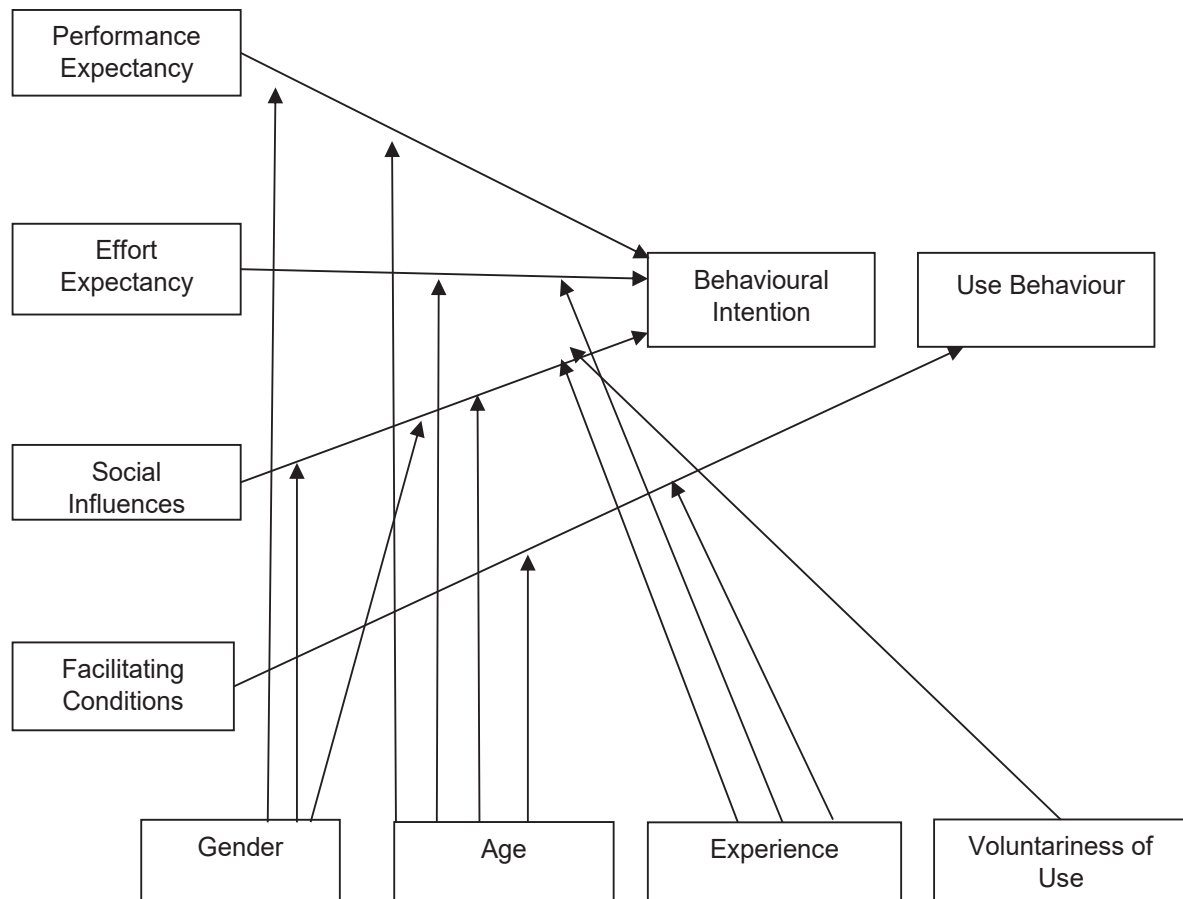
Figure 6: The Unified Theory of Acceptance and Use of Technology (UTAUT)

(Venkatesh et al., 2003)

2.4.1   Description of dimensions of UTAUT

Performance expectancy (PE) is "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003, p. 447). Performance expectancy is considered to be very similar or identical to other constructs in five previous models including; perceived usefulness (TAM and C-TAM-TPB), extrinsic motivation (MM), job-fit (MPCU), relative advantage (IDT), and outcome expectations (SCT) (Venkatesh et al., 2003). PE is believed to be the strongest predictor of BI (Venkatesh et al., 2003).

Effort Expectancy (EE) refers to the degree of ease of using the system, (Venkatesh et al., 2003). The concept of effort expectancy is considered to be very similar or identical to other constructs in three past theories which contribute to UTAUT: perceived ease of use (TAM), complexity (MPCU), and ease of use (IDT), all of which have aspects of ease of learning of a system.

Social Influences (SI) "the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003, p. 451). Aspects of subjective norm (TRA, TPB, and C-TAM-TPB), social factors (MPCU), and image (IDT) are directly related to the social influences variable used within the UTAUT model and the idea that social influences can have a direct effect on behavioural intention to use a new system.

 Facilitating Conditions (FC) refers to "the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh et al., 2003, p. 453). Aspects of facilitating conditions can be seen in three previous models; perceived behavioral control (TPB and C-TAM-TPB), facilitating conditions (MPCU), and compatibility (IDT).

 Behavioural Intention (BI) to use refers to the intention of someone's behaviour to use the system again; it measures future behavioural intention. BI is believed to be the most

important variable of UTAUT as it is the measure of future intention to use a system. BI is a consistent measure within assessing IS usage and is prominent in five of the eight models that contributed to the development of the UTAUT (TRA, TBP, TAM, C-TAM-TPB and IDT).

The UTAUT offers a unified model for analysing technology acceptance by incorporating determinants and moderators of behavioural intention. With the inclusion of *age, gender, experience* and *voluntariness* as moderators in the model it allows the analysis of interactions in more depth than previous models of acceptance (TAM).

In summary, three of the four main UTAUT constructs influence behavioural intention (performance expectancy, effort expectancy and social influences), while the fourth construct (facilitating conditions) and behavioural intention are proposed to have a significant positive influence on usage. Like with many theories the UTAUT have some limitations in that the model has been criticised as being too complex in incorporating multiple models of acceptance (Bagozzi 2007; Van Raaij and Schepers 2008). However, despite criticism of the model UTAUT is still widely acknowledged in several psychological researches investigating the adoption of new technology and will therefore be implemented into the current thesis as a measure of acceptance and behavioural intention to use exergaming as a means of exercise.

2.4.2   The effect of UTAUT on acceptance outcomes

The five dimensions that make UTAUT model each have relative importance associated to the unified theory. Performance expectancy, effort expectancy, and social influences are direct predictors of behavioural intention within UTAUT model (Venkatesh et al., 2003). Essentially UTAUT is analysing future use of new technology and the influences that predict behavioural intention are key contributors to the model. Like with any new technology, exergaming is no different in that companies such as Microsoft and Nintendo want to see their games succeed commercially, yet to the author's knowledge, no research has analysed people's levels of acceptance and intention to use exergames. More so research has partly

looked at enjoyment in exergaming and the motivation to play but not into acceptance of the technology and future usage.

Performance expectancy has been suggested to be the main predictor of behavioural intention (Venkatesh et al., 2003). If people have high levels of PE (believe that the system will help them succeed) then there is a higher chance that they will want to repeat this behaviour and ultimately behavioural intention will be higher as people want to continue using the system. Gender and age are believed to be moderators between performance expectancy and intention. In relation to gender research has indicated that males tend to be highly task orientated (Minton and Schneider 1980 in Venkatesh et al., 2003). In the information technology field alone, research has shown that males perceive the use of computers more useful than their female counterparts (Shashaani & Khalili, 2001). It is believed that men rate perceived usefulness higher than females when making decisions about the usefulness of new technology on behavioural intention (Gefen & Straub, 1997; Sun & Zhang, 2006; Venkatesh &Morris, 2000). Along with gender, age is believed to be a moderating factor that contributes to performance expectancy; it is believed that younger adults have greater emphasis on external rewards which has been linked to PE from the motivational model.

When developing new gaming systems the degree to which a system is easy to use is essential to the developers and also to the players. The ease of use of the equipment (effort expectancy) has been postulated to have a direct effect on behavioural intention (Davis, 1989; Mathieson, 1991; Moore & Benbasat, 1991). It is believed that individuals will purchase and use technology such as mobile phones, iPads, iPhone and commercial games such as the Nintendo Wii if they perceive them easy to use (Davis 1989; Gentry and Calantone, 2002; Venkatesh et al., 2003; Vijayasarathy, 2004). Research has also indicated the females intention to use a system is more strongly related to ease of use (Ong & Lai, 2006; Terzis & Economides 2011).

Social influences are especially important when predicting future usage/intention to use the system again. Social influences have previously been linked to gaming experience, especially that of online gaming. Griffiths and Hunt (1995) found in a study of adolescent gamers that 25% played computer games because their friends did; this was particularly the case in male players. Ducheneaut, Yee, Nickell and Moore, (2006) also suggested that social influences are important in gaming, in particular the aspect of socially been associated with being in a gaming community.

2.4.3   Application of UTAUT in technology

UTAUT is a unified theory to explain user acceptance and intention to use a system. Venkatesh et al., (2003) showed that UTAUT was 70 percent accurate in predicting user acceptance in information technology, as opposed to individual theories alone such as the Theory of reasoned action (TRA), (Ajzen and Fishbein, 1975); or the technology acceptance model (Davis, 1989), which could account for roughly 40 percent of user acceptance. UTAUT was originally developed to assess people's levels of intention and acceptance in an information technology setting; however, research is expanding into wider fields of technology use.

Wang and Wei Shih (2009) used UTAUT to explain why people use information kiosks. They applied the UTAUT to a sample of 244 users (59% males and 41% females) with 29% of the participant's regular users of information kiosks and 71% non-users. The results showed that performance expectancy, effort expectancy and social influences were direct predictors of behavioural intention, with behavioural intention and facilitating conditions having a positive effect on information kiosk use. It was found that performance expectancy was the strongest predictor of behavioural intention. Having both effort expectancy and social influences strong predictors of behavioural intention, indicates that equipment needs to be both user- friendly and used by others (social network/others) to influence behavioural intention.

In relation to information technology, Oye et al (2011) analysed 100 people's technology acceptance using the UTAUT on information computer technology (ICT) in university academics. The results showed that performance expectancy was the strongest predictor of behavioural intention, and effort expectancy also a strong predictor of intention. Therefore the results concur with earlier work of Venkatesh et al., (2003) and Wang and Wei Shih (2009).

The application of UTAUT has developed into the area of mobile computers and mobile phones. Anderson, Schwager and Kerns (2006) used UTAUT to evaluate faculty acceptance of a Tablet Personal Computer (TPC) in a business school faculty. The results showed that performance expectancy along with voluntariness were the greatest predictors of intention. El-Gayar, Moran and Hawkes (2011) later used a modified version of the UTAUT to explain usage of a TPC in 232 college students. The modified version of the UTAUT was effective in predicting acceptance of the use of the TPC. The results showed that performance expectancy has a positive effect on students belief that the TPC will help them attain gains in their school performance as well as having a positive attitude towards future intention to use the TPC($p<0.001$). Furthermore, effort expectancy (ease of use) had a direct effect on people's acceptance of the TPC as well as the intention which is consistent with previous literature (Agarwal & Prasad, 1997; Davis, 1989; Venkatesh, et al., 2003). The results also confirmed that social influences had a positive impact on perceptions of usefulness of the TPC. The results show that overall; student's attitude has the most direct influence on potential intention to use the TPC, followed by facilitating conditions, performance expectancy and social influences. Although the results are somewhat contradicting in comparison to Anderson et al., (2006), as attitude had the greatest direct influence on acceptance not performance expectancy. The results still suggest that performance expectancy whether directly or indirectly (with attitude) can influence intention, indicating the potential of applying the UTAUT.

Along with personal computers and hand- held computer systems, the use of mobile phones and online usage has also been explored using UTAUT to explain levels of potential acceptance towards new technology. Wu et al., (2007) used UTAUT to assess people's level of acceptance using 3G network for mobile phones. Three-hundred and nighty four participants took part in the study with a mean age of 26-35 years old and a mixture of males and females. The results showed that participants using the 3G network showed high levels of performance expectancy, social influences and facilitating conditions which would predict behavioural intention and behavioural intention as a result, would predict actual use of the 3G network. Only effort-expectancy showed to not be an independent predictor of behavioural intention in this study, which supports earlier work of Venkatesh et al., (2003). Qingfei, Shaobo and Gang (2008) used a modified version of UTAUT to analyse mobile-commerce (m-commerce) user- acceptance, they used UTAUT as a theoretical framework for explaining user acceptance and modified the model to include aspects such as system satisfaction, convenience and cost and trust and privacy. They found that factors such as consumer trust to be one of the most important factors in m-commerce and marketing as trust is an important value when buying and online purchasing behaviour. Qingfei et al (2008) believe that the trust variable which is applied to the modified UTAUT is indirectly related to the belief (utility)and should be included in concepts such as ease of use (self-efficacy in UTAUT). The results indicate the potential for applying a modified version of the UTAUT to m-commerce, in particular the modifications that take into account user satisfaction (trust, privacy protection, and cost). The modifications made to UTAUT still need further validation of the modified model, in particular this model was only applied in m-commerce in China, therefore further cross-validation would be needed in order to validate the adaption of the UTAUT.

2.4.4   <u>UTAUT and gaming</u>

The use of the UTAUT has previously been applied in the information technology context and more recently tablet computers and mobile phones however; little has been applied to

the gaming context despite its wide popularity and aspects of addictive behaviour. Chen et al (2011) applied UTAUT to online gaming on mobile phones. Results showed that performance expectancy, social influences, effort expectancy, and facilitating conditions were all significant determinants of attitudes and the attitudes influences the levels of behavioural intention. The research suggests that other dimension such as previous experience of online gaming and internet browsing using mobile phones also had an effect on levels of acceptance.

Ibrahim et al (2011) used UTAUT to explain user acceptance in educational games using students who had no previous experience using educational games as a means of learning. The results showed that over 50% of the students had high performance expectancy in that they believed the educational game can help them perform better. Nighty two percent of the students reported high levels of effort expectancy in respect to ease of use of the educational game and believed they had the skills necessary to use the game. Despite the high levels of performance expectancy, there was no significant relationship between performance expectancy and preferences. This could be because to that the students had no past experience of the educational game and as a result could not rate the effectiveness of the game before use. However, Davis and Venkatesh (2004) contradict this aspect relating to performance expectancy as they demonstrated that performance expectancy can be predicted by initial views at baseline without any physical experience of the equipment.

In summary, there is evidence to suggest the UTAUT can be applied to a wide range of technologies in order to assess future intention and acceptance to use the new technology. Research indicates that performance expectancy and effort expectancy are major determinants of intention to use.

2.4.5 Application of UTAUT to exergaming

To the author's knowledge there is no research which has applied UTAUT to exergaming. The thesis aims to apply UTAUT to exergaming in order to contribute to research in technology acceptance and understand why people would play exergames in the future.

Although it is critical to understand people's behavioural intention to use exergaming as a means to exercise, game-play, fun, enjoyment and therapy it is also highly important to understand the motivational aspects related to exergaming, in particular people's intrinsic motivation to take part in exergaming. Intrinsic motivation is closely linked to flow experience (Csiksentmihalyi 1990).

2.5   Flow

The concept of flow was initially developed when Csiksentmihalyi first watched artists at work; the sense that the artists became totally immersed and in a respect lost in their work became the core foundations for the phenomenon in which Csiksentmihalyi later described as being in flow. Flow is often described as a state in which an individual feels totally immersed in an activity both physically and mentally and nothing else at the time seems to matter (Csiksentmihalyi 1990). Flow has been described as a point in where a person becomes absorbed in an activity (Swann *et al.*, 2012). It is believed that when people experience flow then they are in an optimal psychological state when there is a balance between perceived challenges and the skills involved in the successful completion of the activity (Csiksentmihalyi 1990). Intrinsic motivation is a key concept that is applied to the flow theory in that people participate in activities because they feel intrinsically motivated to do so and are after no external reward or gratification for doing so. The feelings of internal reward are believed to outweigh those from anything externally.

It is believed when people are in flow they perform at full capacity (de Charmes, 1968; Deci, 1975). Research has studied flow in areas of; art and science, (Perry, 1999; Sawyer, 1992), music (Parncutt & McPherson, 2002) sport (Jackson, 1995, 1996), exercise performance (Bakker, Oerlemans, Demerouti, Slot, & Ali, 2011; Pates, Karageorghis, Fryer, Maynard, 2003), gaming (Sherry 2004; Yee 2006) and human – computer interaction (Guo and Poole 2009; Van Schaik and Ling, 2012). Within flow, there are various dimensions which help explain the characteristics associated with achieving 'optimal experience'.

2.5.1   Dimensions of Flow

In order to asses people's flow state, a number of flow state scales where designed in relation to different disciplines, in this thesis the 36-item Flow State Scale (Jackson & Marsh, 1996) was used which was primarily designed to assess flow state in exercise and sporting contexts. The following dimensions make up flow:

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1) Challenge-Skill Balance (CB), occurs when the individual feels a balance between their personal skills and the situation in which they will perform a task in a successful manor. If a task is too easy or too hard then flow will not be achieved; there needs to be an optimal balance between skill level and the challenge of the situation in order to experience flow.

2) Clear Goals (CG) occurs when the individual has clear knowledge and certainty of the activity they are going to perform. They have a pre-set goal in which they are aiming to achieve.

3) Unambiguous Feedback (UF) is when the individual received feedback on their performance allowing the person to "know if he or she is succeeding in the set goal" (Jackson and Marsh 1996).

4) Concentration of Task (CT) is the degree in which the individual is concentrated/focused on the task they are performing.

5) Paradox of Control (PC) this is when the individual performs a task without conscious effort to do so and feels in control during the process.

6) Action-Awareness-Merging (AM) is when the individual performance occurs automatically, this is when a person/athlete becomes absorbed into the activity and does movements without thinking. This is often described as "being at one with the experience" (Csikszentmihalyi, 1992: p.53).

7) Transformation of Time (TT) is the degree in which time either speeds up or slows down during an activity.

8) Loss of Self- consciousness (LS) signifies that the individual's self disappears when they become immersed into the activity in hand.

9) Autotelic experience (AE), where an individual does something because they want to do it and not because they want a reward at the end, usually a form of intrinsic motivation; this is what Csikszentmihalyi, (1990) quotes as being "the end result of flow".

The inclusion of all of these dimensions is what Csikszentmihalyi classes as being in flow and having an autotelic experience. Challenge-skill- balance is believed to be the central concept of flow (Csikszentmihalyi, 1990).

2.5.2   The effect of dimensions of flow state

Each of the nine dimensions of flow has relative importance in explaining the flow theory. If a task or activity are enjoyable to participate in then people are more likely to have levels of intrinsic motivation to perform the activities. With intrinsic motivation comes the aspect of autotelic experience meaning (*auto* = self, *telic* = goal or purpose). Without this intrinsic motivation to participate in the task flow may not be experienced. Likewise, an activity has to elicit a challenge in which the individual feels motivated to achieve realistically, through matching it with the appropriate skill levels and goal setting. In order to achieve these challenges, feedback is essential throughout the process in order to assess the situation. When a person becomes immersed into an activity such as gaming, they experience a sense of control when playing the game as they become lost in the activity. This can be explained in the gaming context when people become that immersed and lost in an activity (action awareness merging) into the game world, and then they can spend hours and days gaming. When in flow people have been noted to have high levels of concentration on the task, these high levels of concentration can relate back to immersion in the activities whereby time can either speed up or slow down (transformation of time) and become somewhat lost in the activity (loss of self-consciousness). For example, Yee (2006) has estimated that online games spend up to 22 hours per week gaming, and have been noted to become lost in the game world.

2.6   Application of Flow

Research into flow has yielded a mixture of results in respect to sporting situations. Flow is believed to be desired by both recreational and elite performers in order to become totally involved/ immersed into the activity (sport) as a means of forgetting other factors which may

affect performance such as fatigue. Research in other domains such as education and arts have shown flow to have a positive effect on performance (Perry, 1999; Sawyer, 1992). Flow is a state in which an individual feels totally immersed in an activity both physically and mentally and nothing else at the time seems to matter (Csiksentmihalyi 1990). It has been linked to improvement in exercise performance (Bakker et al., 2011; Pates et al., 2003). The use of flow applied to exergaming allows a wider understanding or knowledge to assess people's immersion and intrinsic motivation into exergaming.

2.6.1   Flow in Exercise and Sport

Previous literature has shown that flow has been used in sport since the early 1990 (Jackson & Roberts 1992), with positive effects especially within elite athletes, as Catley and Duda (1997) found a person skill level in sport to be significantly related to flow experience. Flow research has also been applied to recreational athletes (Stein et al., 1995). Bakker et al (2012) analysed flow in a group of Dutch soccer players (n=398). They hypothesized that when playing soccer and attaining a draw, then players would experience the highest levels of flow, as opposed to a win, whereby the outcome goal was attained too easy as the opposition may have not performed well or on the other hand when they players lost a match, as the opponents game exceeded the skills of the players. Results showed that mean flow scores where higher when players had a draw (3.73) compared to a significantly lower score when players lost (3.34) and also lower but not significantly different when players won the match (3.60). The results of Bakker et al., (2012) indicated and supported (Csikszentmihalyi's, 1990) earlier work in that the challenge-skill balance was equally matched and enhanced the levels of flow, as the players were performing at optimal levels and were motivated to succeed.

Karageorghis, Vlachopoulos, and Terry, (2000) believed that music may promote flow. Pates et al (2003) analysed the effects of music on flow states in netball shooting in three national league players. Three participants completed 12 shooting tasks with and without music and

asked to complete a flow questionnaire (Jackson & Marsh, 1996). The results showed that shooting performance and flow improved with music during the task in two out of the three players. The one participant which did not experience any changes in flow, but a higher performance in terms of shooting accuracy, showed that performance can increase but flow does not necessarily match objectively measured performance (Jackson & Csikszentmihalyi's 1999).

Swann *et al.,* (2012) conducted a systematic review of flow states in elite sport and found that some flow dimensions where experienced more consistently that others such as concentration of task and action-awareness merging. The use of concentration of task is not surprising in elite performance as optimal concentration is needed in many sports, either before or during the sport itself.

2.6.2 <u>Flow and technology</u>

In relation to gaming, flow research has been successfully applied to online gaming (Voiskounsky et al., 2012), web use (Chen 2004) and human computer interaction (Webster, Trevino & Ryan 1993). It is believed that a precursor of flow is the balance between the skill levels of the players and the challenges for the situation, as a task too easy or too hard will not elicit flow (see Figure 7).
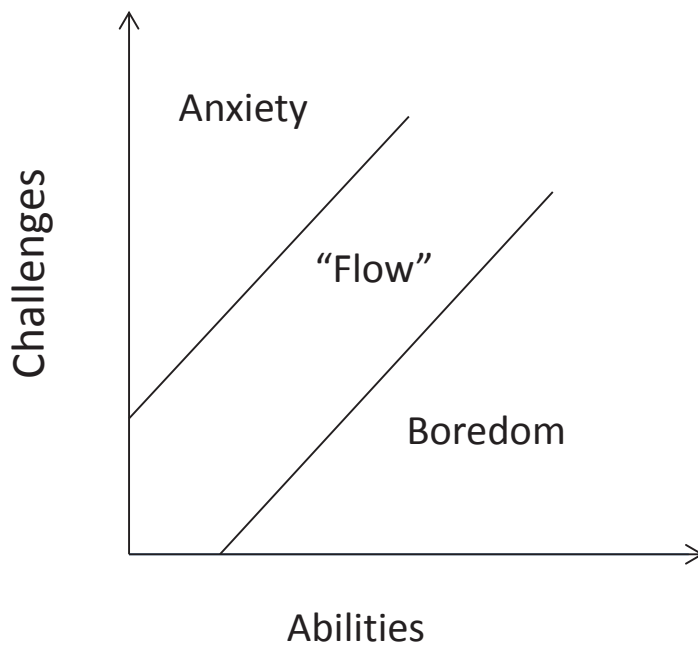
Figure 7: Flow state in work and gaming (Csiksentmihalyi 1975).

2.6.3   Flow and Gaming

Video games have been noted in the past to have addictive characteristics and people often spend hours at a time playing games until proceeding to the next playing level (Sherry, 2004).

Gamers can play against a computer, but more recently there is a surge in online gaming. Online gaming can provide an opportunity of social interaction through the means of virtual technology. Flow has been applied in research to analyse immersive natures experienced during online gaming. Weibel *et al* (2008) analysed flow, presence and enjoyment during online gaming. Results showed that participants who played against human-controlled opponents (online) experienced more flow than those who played against a computer-controlled opponents. Presence and enjoyment were also higher during online gaming. Faiola and Voiskounsky (2007) also concur with the results in that flow was experienced during online gaming. Sherry (2004) stated that video games offer the opportunity for flow

experience to be achieved and also maintained through the use of differing skill level to match the challenge, balance aspect of flow, in that the task is not too easy, nor is it too hard for people to achieve their goals. Flow has been applied to the designs of gaming, specifically online gaming, Chen (2007) believes that in order to develop successful and engaging video games, challenge skill balance is a major component in the development of gaming systems, in that there should be a balance between the challenge of the game and ability of the player, for example progressive increase in the levels of gaming in order to engage users from beginners levels to experts. When designing games it is important for them to be interactive and engaging in order for people to enjoy them and become immersed in the activity. Online gaming has been associated with high levels of immersion as players become lost in the virtual world in which they play.

2.6.4   Flow and Exergaming

The use of flow has successfully been applied to both exercise (Ford and Marsh 2001) and gaming (Weibel *et al.,* 2008). Yet in terms of exergaming (combination of exercise and gaming) there is limited research using flow to explain immersion in exergaming. Previous literature has highlighted the potential use of flow for exergaming including Pasch et al., (2009) and Vernadakis et al., (2012) who both discussed the relevance of flow for enhancing exergaming experience yet failed to measure flow in their studies. They acknowledge that the nine dimensions of flow should occur during exergaming such as the internal reward for playing the games, which is a main characteristic of flow, as the exergames are offering no external reward for playing. Challenge skill balance is also relevant within exergaming, much like with gaming research; games can be tailored in terms of increasing skill level to match player's skills. In order to analyse the effects of flow on exergaming a systematic review was conducted.

2.7 Literature review of user-experience and exergaming

2.7.1 Aims

Exergaming presents an exciting opportunity for a new method of exercise; however, the evidence for why people would use exergaming and the acceptance of exergaming as a means of exercise is unclear. Therefore, we conducted a literature review using a systematic search of the exergaming literature to establish what is known about i) technology acceptance and exergaming; and ii) levels of flow when exergaming. The aim of the review was to critically evaluate the literature regarding exergaming versus non-exergaming controls.

A focused question was developed using the acronym PICO; which stands for Population, Intervention or Issue, Comparatives, and Outcome. Using this framework the following focused question is: In young healthy adults (P) does exergaming (I) effect levels of technology acceptance and flow (O) compared to non-exergaming controls (C).

2.7.2 Study Design

Systematic reviews are designed to limit bias and reduce error in the reporting and synthesis of literature reviews (Higgins & Green, 2005). Using a systematic review as opposed to a narrative report, reduces bias due to having more robust methodological critique of the literature and focusing on specific research questions and has been suggested as a more reliable method for critically analysing the literature (Antman, Lau, Kupelnick, Mosteller, & Chalmers, 1992). The approach to this literature review used a systematic search approach.

2.7.3 Method

Six online databases were searched regarding exergaming and technology acceptance (UTAUT) and flow into exergaming for healthy adults; Science Direct (1823 to 2013); CINAHL® (1982-2013); Cochrance Library (1949 to 2013); IEEE (1872-2013); PsycInfo®

(1880 -2013) and Scopus (1960 to 2013). A general search was firstly conducted into exergaming, and then a redefined search was conducted using the Boolean operators (a method used to control the relationship between term/ components of a search (Murphy & Cowman, 2008). Keywords, titles and abstracts of database entries using the OR/AND operator included: 1) Exergam* OR active video gaming OR Microsoft Kinect OR Nintendo Wii OR Sony EyeToy OR IREX OR Dance Dance Revolution 2) technology acceptance, 3) Flow AND (State* OR Experienc*) 4) enjoyment of exergaming, where * denotes a wildcard to allow for alternate suffixes. Grey literature was also searched (such as generic internet search engines) to avoid missing relevant articles.

In relation to the flow variable the search terms (State* OR Experienc*) was used to replicate Swann et al., (2012) who conducted a systematic review of flow in elite sports. This search term reduced the effects of terms such as "blood flow" occurring.

2.7.4   Article inclusion and exclusion criteria

Inclusion criteria: the titles and abstracts were reviewed from the results found from the online databases. Studies were included if: (1) used young healthy adults, (2) included exergaming, (3) included measurements of flow, UTAUT or enjoyment (4) full scientific paper.

Exclusion criteria: papers were excluded if (1) participants were from a clinical group, (2) the study used children (3) papers were only available in conference proceedings or abstracts or (4) papers were not available in English.

2.7.5   Quality Assessment tool

The methodological quality of each article was assessed using a customised quality assessment tool based on previous systematic reviews (Law et al., 1998; Law 2002; Galna et al., 2009) (see Table 1). In particular the quality assessment tool was used to assess whether sufficient details were provided in the methodology section to be able to

replicate the study. A scoring system was developed to score the quality of each study and assess the methodological strengths and weaknesses of the reviewed articles. A similar quality appraisal scoring system has previously been published in a systematic review (Galna et al., 2009). Each question on the quality appraisal tool was scored out of 1, where 1 indicates high quality research, 0.5 indicates lacking quality and 0 indicates low quality. As exergaming is a relatively new area of research there are limited systematic reviews. Previously those who have performed systematic reviews on exergaming have either not included a quality assessment tool (Taylor, 2011; Peng, Crouse and Lin 2012) or developed one specific for their review (Barnett et al., 2011). Additionally, due to the lack of randomised controlled (RCT's) in exergaming, previously established quality assessment tools such as the Cochrane criteria checklist (Furlan, Pennick, Bombardier and Van Tulder, 2009) cannot be applied to this current literature review. The literature base was judged to be too disparate in methodology and of insufficient quality to allow meaningful synthesis. Therefore as a result a quality assessment tool was designed applying basic components of other tools such as PRIMSA.

[1]**Table 1 Quality assessment tool**

Question	Scoring
1. Are inclusion and exclusion criteria stated?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
2. Are participant characteristics described in detail?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
3. Was Flow state scale described?	1 – Yes
	0 – No
4. Was the design clearly stated?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
5. Was questionnaire reliability stated?	1 – Yes
	0 – No
6. Were exergaming sessions explained in detail?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
7. Were baseline and post testing data presented?	1 – Yes
	0 – No

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[1] Adapted version of a quality assessment tool used for quantitative research (Law, 2002, p.305-308).

2.8 <u>Results</u>

The electronic databases search resulted in a yield of 270 papers (Figure 2.1 1) relating to exergaming and technology acceptance and immersion. Out of the initial yield only four full papers from the original search where included in the review. The papers were found between the years of 2010-2012 relating to Flow only. No papers were found in relation to the UTAUT model and exergaming research.

2.8.1 <u>Study design and methodological quality</u>

Table **9** summarises the design and methodological quality of each article. The study design was not mentioned in any of the papers and limited inclusion and exclusion criteria were given, apart from including young adults, mainly from a university based setting. The use of flow questionnaires were explained in adequate detail, with the majority of the articles stating the internal reliability of each dimension through Cronbachs alpha (a). Baseline and post-test data were presented in all 3 papers. The methodologies included detailed reviews of the exergaming interventions. In general, adequate details were provided to replicate all of the studies.

2.8.2 <u>Sample Characteristics</u>

The number of participants taking part in the interventions ranged from 14 (Thin, Hansen and McEachen, 2011) to 139 (Limperos, Schmierbach, Kegerise, and Dardis 2011). Participant age ranged from 19 to 41 years old with a mixture of males and females (see Table 3).

Figure 2.1 1Flowchart of articles included in the review. The number under the text indicates original articles (i.e. not duplicates) at each stage.

CINAHL n = 4	Scopus n = 35	Science Direct n= 209	IEEE N=20	Cochrane N=1	PsycInfo N=1

Total number of online databases found
270

Number of duplicates
n =5

Number of publication after removing duplicates
n = 265

Number of publications excluded
n=257

Number of publications relevant for flow
N=8

Number of papers excluded **n=4**
Mention flow but no measure **n=3**
Measure of flow in children **n=1**

Number of papers review for flow **n= 4**
No papers reviewed for UTAUT as **0** found.

Table 2: Quality assessment scores for each study

Question	Scoring Criteria	Sinclair et al., (2010)	Limperos et al ., (2011)	Thin et al ., (2011)	Lai et al., (2012)
1 Inclusion/exclusion criteria	1= yes, 0.5= yes lacking detail, 0=no	0	0	0.5	0
2.Participant characteristic details	Number	1	1	1	1
	Age	1	0	1	0
	Sex	1	1	1	1
3.Was flow described	1= yes 0 =no	1	1	1	1
4. Research design clearly stated	1= yes, 0.5= yes lacking detail, 0=no	0	0	0	0
5 Reliability of questionnaires	1= yes 0 =no	0	1	1	1
6 Exergames explained	1= yes, 0.5= yes lacking detail, 0=no	1	1	1	1
7. Baseline and post test data presented	1= yes, 0= no	1	1	1	1
Total		6	6	7.5	6

Table 3: Comparison of exergaming and flow papers

Study	Participants	Flow measures	Results	Limitations
Thin et al., (2011)	14 subjects (9 males)	FSS-2	Improvements over time for total flow for Challenge-Skill Balance and Action–Awareness Merging and Loss of self-consciousness.	Flow was estimated combining cycling based exercise with exergaming.
Limperos et al., (2011)	139 participants (72 females; 67 males)	Adapted flow from Jackson and Marsh (1996)	People playing traditional gaming (play station) showed greater enjoyment and control over Wii™	Only 4 of the 9 subscales of flow were measured. Only one game was compared.
Sinclair et al., (2012)	NA	Dual Flow	No statistical differences, nor where the participants "immersed" in the game.	Small sample size and difference in playing experience.
Lai et al., (2012)	130, with 88 males (68%) and 42 females (32%)	74-item EFSQ (exergaming flow scale)	More frequently and longer time durations for playing exergaming may increase the time spent in flow and also increase enjoyment.	EFSQ too long

2.8.3   Discussion

The aim of this systematic review was to explore what is known about i) technology acceptance and exergaming; and ii) levels of flow when exergaming. Four articles met the inclusion criteria. The review demonstrated that exergaming used as a method of exercise is still very much in the nascent stages of development. The results highlight that the application of flow can partly explain the motivations of why people would use exergames as a means of exercise, however, methodological flaws where present in the four reviewed papers, and thereofre more robust studies need to be conducted before any generalisation can be made regarding exergaming and flow.

Sinclair Hingston and Masek (2010) partly applied flow to exergaming by implementing and designing a dual flow model to exergaming. The dual flow model offers a combination of the attractiveness (flow) of exergaming and effectiveness in terms of physical outcomes. Exergaming was experienced using a GameBike which is a static bike with a computer screen attached to the front offering a range of difference games. Resistance of the bike can be adjusted during the activity to make games more difficult. The dual flow model was applied to the exergaming activity with the flow aspect (attractiveness) showing no statistical differences, nor were the participants immersed in the game. A limitation with the dual flow model, is that it does not take into account all 9 dimensions of flow and is therefore difficult to get a true representation of flow state scale and exergaming. Another possible reason why flow was not experienced could be due to the exergaming system itself. In that riding a bike whilst playing the games did not match participants expectations of exergaming, as despite them being physically activity on the bike, they were not performing full-body movements like other exergaming interfaces offer such as the XBOX Kinect™. Small sample population and difference in physical activity level could have affected the outcome results, as those who are not physically active compared to those who exceeded 10 exercise sessions per week would have had differences in challenge skill balance and perceive the task as too easy or

too hard. As this is the only study regarding flow and exergaming, more robust investigations need to be carried out.

Thin *et al* (2011) analysed the flow experience and mood states in movement-controlled video games (exergaming). Fourteen (9 males) young healthy adults with a mean age of 19 (± 1.5 years) played exergaming based games compared to traditional cycling. Participants took part in three sessions, the first a familiarity session using the exergaming systems, Wii™ and Sony Eye Toy™ using 6 games. Session 2 was the games replayed again with 6 minute cycling on a cycle ergometer and the third session, again, playing the exergames with 6 minutes of traditional bike exercise. Flow was measured using the Flow State Scale-2 Questionnaire (Jackson & Eklund 2002) at the end of the third session, rating the session as a whole including the traditional exercise. Results showed that challenge skill balance, action awareness merging, and loss of self-consciousness were higher in the exercises than in dance. However, a major limitation with these results was that flow was completed based of a combination the three exercises: exergaming, cycle ergometer and traditional cycling; therefore it is difficult to establish if flow was actually present during exergaming alone or due to a combination of exercise. Challenge skill balance dimension is often referred to as the central dimension of flow state (Csikszenrmihalyi, 1990). Despite there being significant differences occurring (p <0.05); it could be due to the ease of activity during the cycling as well as the exergaming which elicited the significant improvements to occur as player's skills were matched. As all exergames were played at a beginner level it would be expected that the participants in the study were novice exergames and had little to no experience of the gaming in order to have an equal challenge- balance skill otherwise if the participants where regular exergamers, then the task would be too easy to complete and would not necessarily experience flow in respect to challenge balance skill. However, the authors do not mention the experience of the participants in relation to exercise levels or exergaming experience which makes the results hard to generalise to exergaming. Having compared the results against dance and exercise norms, the authors do not include any information regarding the

characteristics of these results for instance in dance, the level of ability, the gender or the age which may have factors on flow results, as it is believed elite athletes possess more time spent in flow (Catley and Duda 1997). Another limitation with the study is the small sample design, which makes results hard to generalise.

Limperos et al (2011) analysed the levels of enjoyment and flow between playing on the Nintendo Wii and Playstation 2 (PS2) playing Madden, an NFL- football based game and, tested the differences for 139 students (72 F, 67 M) who were split into either the Wii group (n=78) or the PS2 (n =61). During the intervention, three levels of play were conducted for both groups playing either 1) against the computer, 2) against a confederate (another player) or 3) playing with a confederate against the computer. Flow state was assessed using a reduced version of Jackson and Marsh (1996) where only challenge skill balance, concentration, sense of control and transformation of time where analysed. The results showed that those playing the PS2 experienced significantly higher levels of enjoyment ($p<0.05$) and control ($p <0.01$) over the Wii. Gender had a significant effect on enjoyment ($p<0.05$), control, ($p<0.001$), and optimal skill/challenge ($p<0.001$). There was, however no significance established for gender between exergaming systems (Wii and PS2). Significant differences were established with regards to performance with participants performing better on the PS2 than the Wii ($p<0.001$) and males had significantly greater net scores overall ($p<0.01$). Overall the effect of previous experience was not a significant predictor ($p>0.05$). It was suspected that when playing the PS2 the success of the game was higher compared to the Wii, which may have had significant influences on enjoyment and flow. The results suggest that the dimension of control from the flow was the most influential dimension to be measured, rather than actual game performance. A limitation with this study design was that in relation to exergaming, only one system was active (the Wii) whereas playing on the PS2 was traditional gaming with no exercise, which questions the true relevance of the comparisons between the two systems. Furthermore, because only one game was studied, it is hard to justify any true generalised view in relation to flow. Another limitation of the study

was that when analysing flow only four out of the nine subscales of flow were tested, as a result because only four dimensions of flow were measured, it is not certain whether there would have been an effect on these.

Lai, Wang and Yang (2012) designed a modified version of the Flow State Scale questionnaire consisting of 74 items as opposed to the traditional 36 item questionnaire (Jackson and Marsh, 1996) to assess peoples flow during exergaming. The results showed that people who play exergames more frequently and for longer time durations may increase the time spent in flow and also increase enjoyment. However, although the questionnaire showed the rationale for flow to be measured in exergaming, the questionnaire is too long and a shorter version needs to be applied to research (Lai et al., 2012). A methodological issue with the study is that the questionnaire was sent to a range of participants (n = 130) who had different experiences, length or play and different exergaming systems. Participants were asked to recall a time where they experienced flow then to fill in the questionnaires. Having participants to recall flow could potentially hinder the results, as the authors already assume that the exergaming systems produce flow. Furthermore, the use of playing the games using multi- player mode (76%) could have affected the flow results. By adding a friend or additional player to the exergame could have an effect on the flow state as the level of enjoyment they were experiencing could be due to social influences such as having friends around or playing against someone. Previously gaming research has indicated the preference of players to play multi-player mode compared to against the computer, alone (Weibel *et al.,* 2008).

Table 4: Description of the four studies included in the review

Study	Participants	Intervention	Quality Rating	Comparisons
Thin et al., (2011)	14 subjects (9 males; 5 females)	Single gaming intervention 6 minutes gaming plus 6 minutes cycling	7.5/9	Flow State Scale-2 Questionnaire (Jackson & Eklund 2002). Completed post-exercise
Limperos et al., (2011)	139 participants (72 females; 67 males)	Single gaming intervention Played split into Wii or Playstation 2 playing 3 different levels: 1) against computer, 2) against confederate, 3) with a confederate	6/9	Adapted version of Flow state scale (Jackson & Marsh 1996) with only challenge skill-balance, concentration of task, sense of control and transformation of time measured. Completed post-exercise
Sinclair et al., (2012)	Not mentioned	Single gaming intervention Game flow using bike	6/9	Dual flow model, with challenge skill balance measured with intensity and fitness (effectiveness).
Lai et al., (2012)	130, with 88 males (68%) and 42 females (32%)	Recall questionnaire sent to gamers	6/9	Extended Flow state scale, Questionnaire was sent out to participants to recall experiences of Flow.

Note: This table shows the characteristics and quality scoring of the four studies included in the literature review.

2.9   Summary of literature review

Table 4 summarises the results found in the systematic review from the four articles found relating to exergaming and flow. The results found variations in methodological design for the questionnaires, as none of them used the same questionnaire; they either used modified versions of the flow state scale questionnaire, extended versions or FSS-2. In particular when analysing exergaming game flow, Thin et al., (2011) combined the experiences in traditional exercise with exergaming as opposed to exergaming alone. This is an obvious source of bias and error as there is no clear indication as to whether improvements in flow can be truly attributed to exergaming alone or a combination of the exercises. The feasibility of exergaming may have affected the results, as there was no mention regarding actual ability to play the games and only limited information regarding previous game play (Limperos et al., 2011; Lai et al., 2012). If the games were too challenging for the individuals then this could have affected flow states in a respect of not achieving challenge-skill balance. As no results were reported regarding ability to play then this can only be speculated.

The results from the systematic review highlight both the relevance and novel aspect of applying flow to exergaming in order to gain a wider understanding of the motivation and to use exergames as a means of exercise. Previous literature has shown that the UTAUT is a well validated model for analysing technology acceptance, over single theories alone and acceptance of a new technology is fundamental to understand the mechanisms for continued use (behavioural intention) of the system (Venkatesh et al., 2003). In respect to flow, literature has shown the potential of using flow to understand motivation to play sport, exercise, and gaming. The current thesis will expand on recent literature which has examined aspects of exergaming and flow and add the UTAUT theory in order to gain a wider understanding of the psychological of exergaming.

2.10 Dual Approach

The psychology of exergaming is an important aspect of the thesis to investigate the motivation and acceptance towards exergaming. However, there is little known regarding the physiological effects of exergaming over mirror matched gym based exercise with no virtual stimuli. Although there is evidence to suggest exergaming can elicit moderate energy expenditure (O'Donovan et al., 2012; Graves et al., 2007; Bosch et al., 2012; Lanningham-Foster et al., 2009; Graf et al.,2009) there is limited research regarding the potential improvements in balance through exergaming. Balance was specifically chosen in the thesis as it is a key functional activity used for daily living and currently there are no current guidelines prescribing the "gold standard" method of training to improve balance.

2.10.1 Understanding Postural control and Balance

2.10.1.1 Balance/Stability

Postural stability (balance) is the ability of an individual to maintain their centre of mass (COM) or equilibrium within a base of support, (Shumway-Cook, & Woollacott, 1995). When maintaining balance a person should remain within the base of support (area in contact with the ground). A person can be unbalanced when the line of gravity falls outside the base of support (BoS), (Pollock et al., 2000). When a person is subject to feelings of being unbalanced, muscular activity will counteract the force of gravity in order to prevent a fall (Horak, 1987). When a person is performing a balance task, they are believed to be more stable when there is larger BoS (two footed as opposed to one), (Pollock et al., 2000). Humans have control over balance (postural control) in order to prevent falls from occurring, (Pollock et al., 2000).

2.10.1.2 Postural Control

Postural control is a complex motor skill which requires and interaction between multiple sensorimotor processes (Horak & Macpherson, 1996). The term postural control "involves controlling the body's position in space for dual purposes of stability (balance) and

orientation" (Shumway-Cook and Woollacott 1995) and is active in all positions (supine, sitting, standing). Postural orientation is the ability to maintain an appropriate alignment between body segments, and between the environment for the task and the body (Horak & Macpherson, 1996). During postural orientation there is an "active control of the body alignment and tone with respect to gravity, support surface, visual environment and internal references" (Horak, 2006). Postural stability (balance) is the ability of an individual to maintain their centre of mass (COM) or equilibrium within a base of support, (Shumway-Cook, & Woollacott, 1995).

During postural activities, postural control can be affected by alterations from the individual, the demands of the postural tasks, and the environment constraints, (see Figure 8)
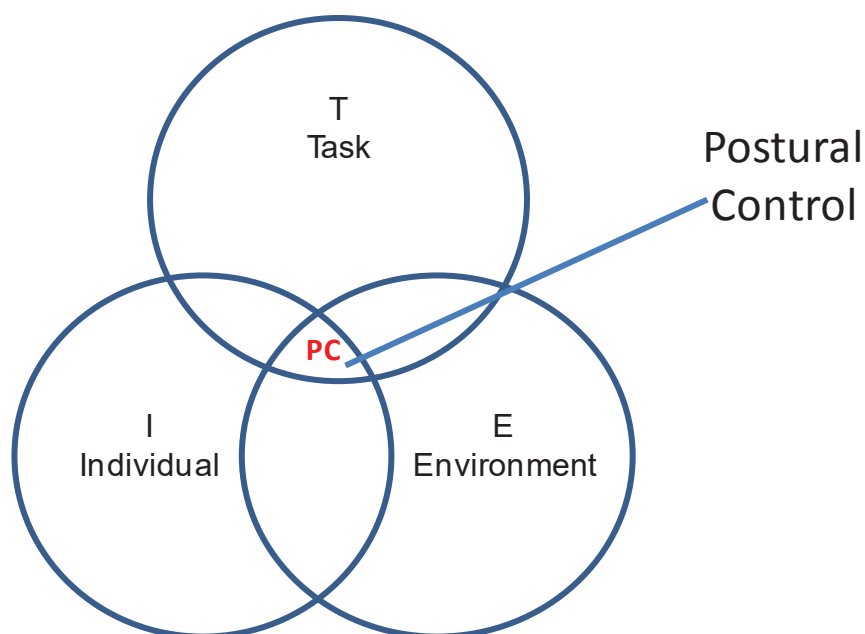
Figure 8: Postural Control interaction (Shumway-Cook and Woollacott 1995).

During postural control there are believed to be six main physiological factors that can have an effect on a person's postural control (See Figure 9 for breakdown of resources).
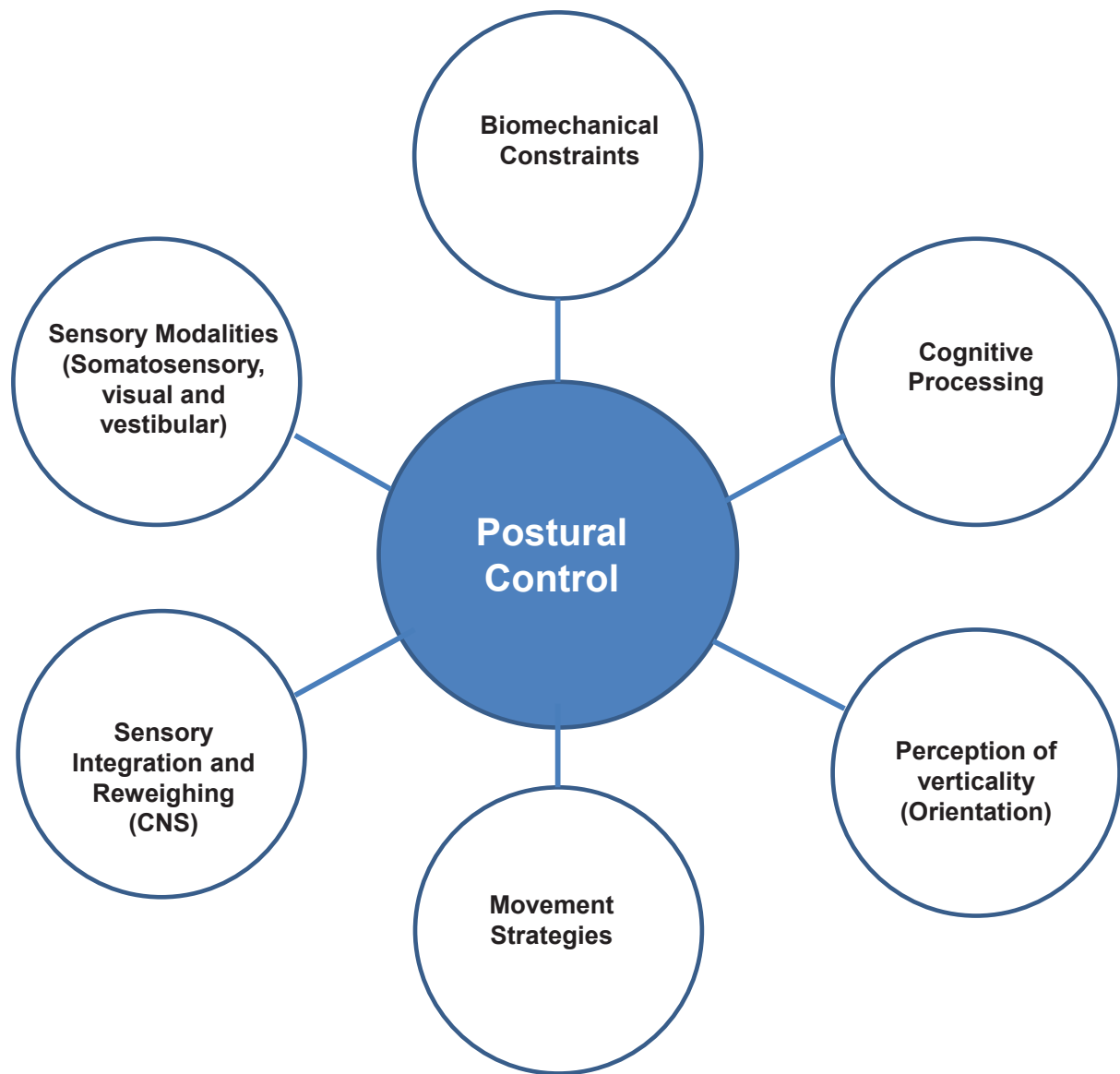
Figure 9: Physiological resources required for postural stability and orientation (de Oliveria et al., 2008; Horak 2006)

2.10.2 <u>Sensory strategies and reweighing</u>

Massion, (1992) acknowledged that for the human postural system to operate in an efficient manor it must take into account the integrated information from three independent sensory sources: somatosensory, vestibular and visual inputs (spatial orientation), which are all controlled by the central nervous system (CNS). Sensory information is constantly changing due to the environment, task and individual. The CNS gives priority to one of the 3 sensory systems (somatosensory, vestibular or visual) depending on the task, environment or individual when maintaining postural control. When standing on a flat, stationary surface in a controlled environment, it is believed that the somatosensory system is responsible for 70% of the information required to maintain postural control, with the vestibular system accounting for 20% and the visual system responsible for 10% of the postural control mechanisms, in healthy adults (Peterka 2002). The use of the three sensory sources allow the body to assess the position and motion of the body in space, and is constantly challenged by differences in the environment (i.e. change of surface). The term sensory reweighing is the ability to rely and choose on different sensory input, depending on the condition of the postural stability activity. For instance when standing on an unstable surface (foam) the CNS increases the sensory inputs from the vestibular and visual systems and reduces the information from the surface somatosensory inputs (Peterka 2002). Therefore, if any decrement in one or more of the sensory systems is damaged or impaired it will results in altered postural stability. The use of the sensory system can be acknowledged during daily living such as when there is a change in surface the visual system takes predominance over the other sensors.

2.10.3   Biomechanical constraints

In relation to biomechanical constraints the size and quality of the base of support: the feet; is considered to be the most important constraint on balance (Tinetti et al., 1988; Horak, 2006). Factors that can affect balance at the feet are concerned with limitations in strength, range, size, pain and control of the feet (Tinetti et al., 1988). Secondary during postural control the human body controls the centre of mass in relation to the base of support. When standing statically "the limits of stability —the area over which an individual can move their CoM and maintain equilibrium without changing the base of support are shaped like a cones " (see Figure 10), (Horak 2006; Shumway-Cook and Woollacott 1995), whereby individuals can move their body in a given direction without losing balance, stepping, or reaching for assistance. Maintaining the limits of stability has been noted as another biomechanical constraint (Horak, 2006). It is believed that limits of stability are not fixed; in fact they change in accordance to the task, the individual and the environment (Pai et al., (2000). The central nervous system has an internal representation of the cone of stability (see Figure 10), and any detriments in balance can lead to small representations of the cone of stability.
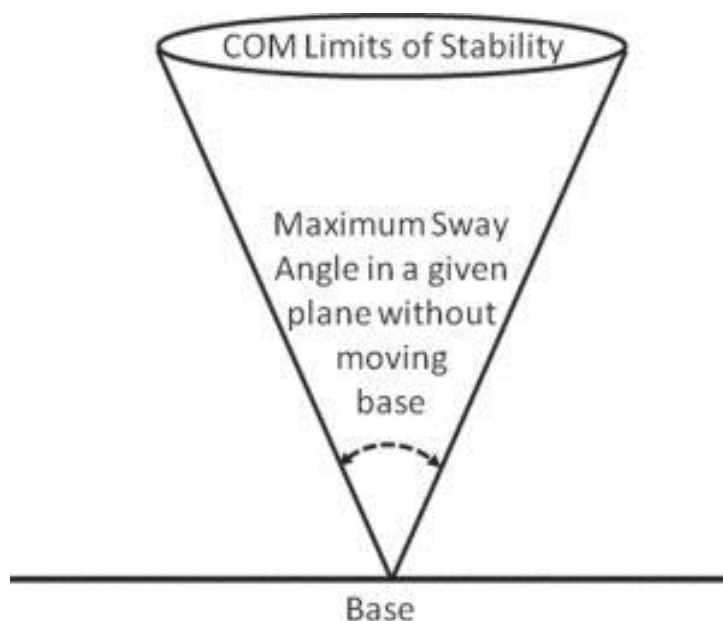
Figure 10: Representation of Limits of Stability

2.10.4 Movement Strategies

During postural stability there are three types of movement strategies which can be used to maintain equilibrium within a base of support; ankle strategy, hip strategy and steeping strategies (Nashner and McCollum 1985; Horak, 1987). When standing on a firm surface with small perturbations, the ankle strategy will take place, whereby the ankle joint helps control stability by producing torque at the ankle and restoring the COM to a stable position. When restoring the COM to a stable equilibrium the muscles around the ankle (i.e. Gastrocnemius, tibialis anterior) are primarily responsible for minimizing the amount of sway, (Lee and Lishman 1975; Winter et al., 1998). Whereas during more difficult standing balance activities (one legged standing, standing on a narrow surface) the hip strategy takes place producing fast, rapid movements at the hip joint to control the COM and restore equilibrium (Horak & Nashner, 1986) and use hip abductors (gluteus medius and tensor fascia latae) and adductor muscles to help restore equilibrium especially in the medial lateral direction, (Maki et al., 1994b; Winter et al., 1996; and Horak & Moore, 1989). Stepping strategies are primarily used when the ankle and hip strategies are insufficient to recover balance. Research has indicated that stepping strategies are more common in people with a risk of falling (Maki, Edmondstone and McIlroy 2000).

2.10.5 Cognitive Processing

Cognitive processing is needed during postural control tasks, especially when greater attentional demands are needed due to increased difficulty of the standing tasks such as when attentional interference between postural control and cognitive processes is high (Wollacott 2000). Other varying factors which may need greater attentional requirements are age of the individual and balance abilities (Wollactott & Shumway-Cook, 2002). When performing dual tasks such as recalling numbers or words when performing postural stability

(static standing) tasks attention is divided between the sensorimotor and cognitive tasks (Huxhold et a., 2006). When performing dual tasks research has indicated that balance performance is compromised compared to static standing without additional cognitive processing, (Andersson et al., 1998; Condron, & Hill 2002; Maylor, & Wing 2000; Melzner et al., 2001; Pellecchia, 2003). Dault et al., (2001) contradicted this notion in finding that in a sample of young healthy adults (mean age 23.0) that when performing dual tasks centre of pressure displacements was reduced in comparison to single task balance, this was also supported by (Dault et al., 2001; Dault et al., 2003; Deviterne et al., 2005; Jamet et al., 2004; Riley et al., 2003). Huxhold et al., (2006) suggested that during simple dual task activities centre of pressure displacement reduced compared to single task in both young and old healthy adults, whereas when the dual task became difficult, there was an increase in centre of pressure displacement for dual task compared to single, as more cognitive processing had to be split between postural control and cognitive tasks, rather than postural control alone.

2.10.6   Orientation in space (Perception of Verticality)

The ability to orient the body parts in respect to gravity, visual surround, the support surface and internal references is essential to maintain postural control (Horak, 2006). When performing a variety of postural tasking, the human body is subjected to variations in surface, gravity and the environment of the task. When performing more dynamic postural task such as rotation of a force platform, then the subject can orient their posture to match in respect to gravitational forces, for example standing on a moving platform, the body moves with gravitational pulling forces to enable maintenance of balance. Likewise with changes in visual surround the use of visual inputs provides a reference for verticality, in that many visual objects appear in vertical alignment (i.e. doors) and can help maintain postural control.

2.11 Balance and exercise

Balance is a key component of fitness and should be included within exercise program (Garber et al., 2011). Functional balance training is used frequently in sports especially in sports that require good levels of balance to succeed in their sport. Davlin (2004) found that elite gymnasts had better dynamic balance compared to elite soccer players, swimmers and non-competitive athletes. Similarly in a study of healthy, young female dancers and soccer players, Gerbino et al., (2007) found that in 5 out of 10 balance tests the dancers significantly performed better than the soccer players. The results from both studies may indicate that the gymnasts and dancers have better functional balance due to both sports needing fine postural control.

2.11.1 Exercise Interventions to Improve Balance

Balance based exercise programs are frequently used in both rehabilitation and sporting performance to improve stability and postural control and help reduce falls in the elderly. Common exercise interventions which have been advocated to help improve balance are Thai Chi (Lin et al., 2006; Au-Yeung et al., 2009), wobble board based exercises (Emery et al., 2005), and core stabilization exercises (Muthukrishnan et al., 2010). Specific balance based exercise interventions including activities such as sit to stand; dance; and fast walking have also been used in balance based exercise interventions with good success in older adults (Barnett et al., 2003). Although previous research has demonstrated the potential of specific and general exercises to improve postural control, the amount of people regularly taking part in balance based training is low due to the tedious nature of the training. An alternative method of exercise which has recently been used to train balance is exergaming (Bateni 2011; Toulotte, Toursel and Olivier 2012).

2.12 **Literature review on exergaming and balance in young healthy adults**

2.12.1 **Introduction**

Balance was specifically chosen in the thesis as it is a key functional activity used for daily living and there are no current guidelines prescribing the "gold standard" method of training to improve balance. In order to develop a more robust methodological approach to exergaming and balance training, a literature review was performed using a systematic search as it is believed to be a more reliable technique than a narrative report (Antman, Lau, Kupelnick, Mosteller, & Chalmers, 1992).

2.12.2 **Aim**

The aim of the review was to critically evaluate the literature regarding exergaming versus non-exergaming controls.

A focused question was developed using the acronym PICO; which stands for Population, Intervention or Issue, Comparatives, Outcome and Study design. Using this framework the following focused question is: In young healthy adults (P) does exergaming (I) effect balance (O) compared to non-exergaming controls (C).

2.12.3 **Method**

The following databases were searched electronically with no time limit on the searchers (Science Direct; CINAHL®; Cochrance Library; IEEExplore; Scopus; Web of Knowledge). A general search was firstly conducted into exergaming, then a redefined search was conducted using the Boolean operators (a method used to control the relationship between term / components of a search (Murphy & Cowman, 2008) to combining key words from the following concepts using the AND/OR operators: 1) Exergam* OR active video gaming OR Microsoft Kinect OR Nintendo Wii OR Sony EyeToy OR IREX OR Dance Dance Revolution (DDR); 2) postural control OR posture; 3) balance; 4) healthy young populations, where *

denotes a wildcard to allow for alternate suffixes. Grey literature was also searched (such as generic internet search engines) to avoid missing relevant articles.

2.12.4 Article Inclusion and exclusion criteria

Inclusion criteria: the titles and abstracts were reviewed from the results found from the online databases. Studies were included if: (1) they used healthy young adults (2) exergaming compared to balance exercise or had a control group, (3) included objective measurements of postural control, (4) full scientific paper.

Exclusion criteria: papers were excluded if: (1) participants were from a clinical group, (2) only subjective measures of balance were reported, (3) if the only intervention was exergaming, (4) if only conference proceedings or abstracts were available, (5) if there was only a review of exergaming published but no trial mentioned, (6) papers not available in English.

After removing duplicate publications a systematic review was performed using a limited number of trials (see Figure 11 for breakdown of searches).

A quality assessment was performed based on the specific journals included into the review. A custom made set of questions were designed in order to make the reviewing process more robust and reduce bias occurring, (Law 2002; Galna et al., 2009), (see Table 5). Like other reviews in exergaming, because of the lack of good quality RCT-level evidence it was decided to adapt a method of assessing the quality of the studies. The adapted approach includes the basic components of other tools but does not apply, nor claim to apply, the same degree of rigour as the likes of PRISMA, which, it was felt would be more appropriate for studies of a standard quality.

Figure 11: Flow chart of articles included in the review: The number under the text indicates the number of original articles (i.e. not duplicates) each stage of the search

| CINAHL n = 91 | Scopus n = 50 | Science Direct n= 50 | IEEE N=114 | Cochrane N=1 | Web of knowledge N=728 |

Total number of online databases found n =332

Number of duplicates n =9

Number of publication after removing duplicates n = 323

Number of publications excluded n=301

Number of publications relevant for flow n=22

Number of papers excluded **n=19**
No other intervention exercise group **n=10**
Used an elderly subject cohort **n=5**
No objective measure of balance **n=1**
General review of Wii **n=2**
Abstract only **n=1**

Number of papers review for young healthy adults **n=3.**

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Table 5: Quality assessment tool for exergaming literature

Question	Scoring
1. Are the research aims clearly stated?	1 – Yes
	0 – No
2. Are the inclusion and exclusion criteria clearly stated?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
3. Are participant characteristic explained in detail?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
4. Was sample size justified?	1 – Yes
	0 – No
5. Where force plate methods described in detail?	1 – Yes
	0 – No
6. Was randomisation of groups explained?	1 – Yes
	0 – No
7. Was the design clearly stated?	1 – Yes
	0 – No
8. Were duration and intensity of exercise programs explained?	1 – Yes
	0.5 – Yes, lacking detail or clarity
	0 – No
9. Were the exergaming and other exercise explained?	1 – Yes
	0 – No

2.13 Results

The electronic databases search resulted in a yield of 358 papers relating to exergaming and postural sway. Nine papers were duplicates and papers which did not fulfil the inclusion criteria were excluded, three papers met the inclusion criteria.

2.13.1 Methodological quality

In order to objectively discuss the quality of the results a modified version of a scoring system developed by Law (2002) was used to examine the internal and external validity of the studies. Only one previous systematic review has been published regarding the benefits of exergaming with regards to the Nintendo Wii only, (Taylor, 2011) however, no quality assessment tools were mentioned in the paper therefore, for the purpose of the current thesis a quality appraisal tool was designed in relation to exergaming, analysing the reliability and validity of each study (see Table 5). A scoring system was developed to objectively analyse the quality of each study and to assess the methodological strengths and weaknesses for the current literature. Scores of 1 indicated good evidence, 0.5 limited evidence or 0 no evidence, higher scores indicated greater methodological quality this scoring system was adapted from previous systematic reviews (Galna et al., 2009). Mean scores were developed of each of the 9 questions to assess the quality of the paper, scores close to 1 showed good high quality research and scores close to zero showed poor quality research with flaws in various aspects of the paper.

Table 6 summarises the quality of each article. The aims were explained well, with the majority of the articles detailing exclusion criteria, but failing to mention the inclusion criteria. Participant's characteristics were explained with evidence of age, sex and number of participants. Only one paper used a randomized controlled trial (RCT) method (Fitzgerald et al., 2010) where randomization was explained. There was limited information regarding sample size justification. The methodologies included detailed reviews of the exercise programs, in particular the exergames that were played (Wii™ and wobble board). Outcome measures of postural sway were detailed in a good amount of information. Details were adequate to replicate all of the studies.

2.13.2   Sample Characteristics

The number of participants ranged between studies from 25 to 36 (see Table 7) Participant's age ranged from 19.56 ± 1.69 years to 26.9 ± 3.2 years old (actual mean) with a mixture of males and females. Participants were recruited if they were healthy young adults.

Table 6: Quality assessment scores for each study

Question	Scoring Criteria	Brumels et al (2008)	Fitzgerald et al (2010)	Vernadakis et al (2012)
1. **Are the research objectives clearly stated**	1= yes, 0.5= yes lacking detail, 0=no	1	1	1
2. **Inclusion/exclusion criteria detailed**	1= yes, 0.5= yes lacking detail, 0=no	0.5	0	0
3.Participant characteristics	Number	1	1	1
	Age	1	1	1
	Sex	1	1	1
4. Sample size justified	1= yes, 0 =no	0	0	0
5. **Were force plate methods described**	1= yes, 0.5= yes lacking detail, 0=no	1	1	0.5
6. Randomisation explained	1= yes, 0.5= yes lacking detail, 0=no	1	1	0.5
7. Research design clearly stated	1= yes, 0.5= yes lacking detail, 0=no	1	1	1
8. **Duration and intensity of exercise explained**	1= yes, 0.5= yes lacking detail, 0=no	1	1	1
9. Exergaming sessions explained	1= yes, 0.5= yes lacking detail, 0=no	1	1	1
Total Score		**9.5**	**9**	**8**

Table 7: Author, participants, exergame, intervention and intensity explained.

Author	Participants	Exergame	Control Group	Games	Intervention	Intensity
Brumels et al., (2008)	25 young healthy adults Mean age ± 1SD 19.56 ± 1.69 years	Nintendo Wii Fit ™ Dance dance revolution (DDR)	Traditional exercise Using mini trampoline Star Excursion Balance Test (SEBT)	Wii- Ski Slalom, Table Tilt, Balance Bubble	3 sessions/Week 4 weeks 12-15 minutes each	NS
Fitzgerald et al., (2010)	28 young healthy adults Mean age ± 1SD 25.4 ± 2.1 (VR group) 26.9 ± 3.2 (no VR)	Interactive balance board	Wobble board	No games mentioned	3 sessions/Week 4 weeks 15 minutes each	Progressed every third week in the intervention (4 times in total over 12 weeks)
Vernadakis et al., (2012)	32 young healthy adults Mean age ± 1SD 20.56 ± 0.62 years	Nintendo Wii Fit ™	Traditional exercise Using mini trampoline Star Excursion Balance Test (SEBT)	Tree, standing knee, king of dance, soccer heading, table tilt, penguin slide, ski slalom, tightrope walk, snowboard slalom, balance bubble	2 sessions/week 8 weeks 24 minutes	7out of the 10 games increased in intensity

Note: NS= Not stated, DDR = dance dance revolution.

Table 8: Descriptions of the three studies included in the review

Author	Inclusion Criteria	Exclusion Criteria	Design and Aims	Outcomes	Quality Score	Key Findings
Brumels et al., (2008)	NS	Previously diagnosed condition inhibiting balance or significant history of injury/surgery on their ankles. Not in a strength and conditioning or not competitive athletes	Pre-Post-test. To compare the efficacy of traditional and video game based balance programs for improving balance and compliance	Star excursion balance test (SEBT) Two 10 seconds unipedal trials with eyes open and eyes closed Enjoyment questionnaire	9.5/11	Improvements in Wii and DDR for average deviation in the y-axis No improvement in traditional group Wii and DDR perceived as been less strenuous and more enjoyable
Fitzgerald et al., (2010)	NS	Musculoskeletal injury, neurological disorder or vestibular impairment	Randomized controlled trial (RCT) To compare the effects of wobble board exercises with and without virtual feedback on dynamic stability and intrinsic motivation	Dynamic balance- double limb jump landing on single limb SEBT The Self-Motivation Inventory (SMI) The Intrinsic Motivation Inventory	9/11	No difference between exercise groups for dynamic balance. Improvements in both groups for posteromedial and posterolateral direction in the SEBT Greater level of enjoyment and interest in the exergaming group
Vernadakis et al., (2012)	NS	NS	Pre-Post-Test To determine whether there was any difference between and exergame and traditional balance program.	Dynamic Balance (Biodex) Single leg static balance	8/11	Both exercise groups showed improvements in SI, API and MLI.

Note: NS= not stated, SI = stability index, API = anterior-posterior index, MLI = medial-lateral index.

2.13.3 Discussion

Results from all three studies showed improvement in balance over time (Brumels et al., 2008; Vernadakis et al., 2012; Fitzgerald et al., 2010) from baseline to post-test (see Table 8). Brumels et al., (2008) showed significant improvements by a reduction of anterior posterior postural sway in both the Dance Dance Revolution™ (p = 0.028) and Wii™ group (p = 0.043) over time but no improvement for the traditional exercise group. However, the paper acknowledges that all three groups showed improvements from pre to post testing with eyes open. As there is no baseline or post test data published in the paper it is hard to determine whether the traditional group may have been close to statistical significant and also what the mean differences between testing were. Another methodological issues is that during static standing there is only an indication that the participants only performed one repetition of eyes open and eyes closed for 10 seconds on their dominant leg. Only performing one trial can lead to high levels of variations within the results (Le Clair and Riach 1996) and should be interpreted with caution. This will be discussed further in chapter 3 for the review of methodological techniques. Results between groups showed that the two exergaming groups (DDR™ and Wii™) significantly improved their CoP displacement over the traditional exercise group (p=0.014, p=0.028) respectively. Results from the SEBT balance test showed that the traditional exercise group had significant improvements over time in the anteromedial (p =0.004) and medial (0.027) directions, yet no results were reported for either exergaming groups either for pre-post-test analysis or between exercise groups, therefore it is difficult to distinguish any improvement in the SEBT test for the exergaming groups as no results were published. The fact that the traditional exercise groups trained for four weeks using the SEBT could have had a factor on why the traditional exercise group showed significant improvement over time, as a learning factor could have occurred. Interestingly, no results from the control group were reported at any point during the paper, despite stating that controls where tested pre and post intervention.

Vernadakis et al., (2012) results concurred with Brumels et al., (2008) in that there were significant improvements over time (p < 0.001). However, no statistical differences were found between exercise groups for AP sway. The games played in both studies using the Wii Fit™ used the same games, the only difference was that Vernadakis et al., (2012) used more games and played them for longer periods of time. For medial-lateral (ML) sway improvement from pre and post-tests also occurred producing statistical significance in both the traditional and exergaming group but no significance between groups. The mean results from pre and post test scores showed that the traditional exercise group has lower AP and ML scores at both pre and post testing compared to the exergaming group, yet the exergaming group had a larger mean difference over time with a score of 1.54 compared to 1.52 in the traditional exercise group, this was however, minimal in respect to between group differences. The opposite occurred over time for ML with the traditional exercise groups showing a greater mean difference of 0.44 compared to 0.42 in the exergaming group, again a causing a 2mm difference in scores. The results would indicate the potential of using both methods of exercise and agree with earlier work of Brumels et al., (2008) that the Wii™ can be useful for showing improvements in balance, in particular AP sway over time.

The results from the Fitzgerald et al., (2012) showed that there was no statistical significance between groups for any of the baseline measures. There was statistically significant differences occurring over time for both groups for improvement in posteromedial and posterolateral direction on the SEBT, with the exergaming group showing a greater improvement in the posteromedial direction with a large effect size of 0.91 and the control group had a larger improvement from baseline for the posterolateral direction with a large effect size reported at 1.13. There were no significant differences established either between or within – group differences for dynamic postural stability assessment. In relation to the intrinsic motivation, the exergaming group showed significantly higher (p < 0.01) scores for interest and enjoyment category. No other significance was established between the exercise groups post exercise, however it should be noted that the exergaming group

showed higher mean scores on all subscales of the questionnaire, with both groups scores moderately similar scores for perceived value/usefulness. No baseline data was reported in the paper for the questionnaires so it was not possible to analyse any within- group differences occurring nor were any effect size mentioned. The results would suggest that both wobble board training and exergaming based training do have beneficial effects on dynamic balance in relation to the SEBT and the exergaming did show a greater level of enjoyment during training. Possible reasons why there was no significance occurring between groups could be due to the fact that they both used wobble boards as a method of training, whilst the exergaming used randomized movements in all directions, the control group had a more structured regime and used movement in both the AP and ML direction as well as rotational movements. As this is the only RCT it exergaming for healthy young adults it is hard to make any direct comparisons, with a moderate number of participants completing the intervention (n=22) the results should be taken with caution.

2.13.4   **Balance outcomes**

The balance outcomes differed considerably between the three studies in respect to the duration, repetition and the nature of the balance test (static or dynamic). Both Brumels et al., (2008) was the only study to analyse postural control during static unipedal standing, however the duration was short (10 seconds) and only one trial was performed for eyes open and one for eyes closed, which could lead to wider margins or error (this will be discussed in more detail in chapter 3). Fitzgerald et al., (2010) used a static force platform, however they assessed dynamic balance by jumping then landing on one leg and remaining this stance for 10 seconds, this was repeated three times. Vernadakis et al., (2012) followed a similar postural sway outcome measure of Fitzgerald et al., (2010) in that they measured dynamic balance, although no jumping was performed, participants had to maintain unipedal stance whilst on an unstable platform for 20 seconds, this was repeated three times.

2.14 Related studies

As only full papers were included in the review it should be noted that an abstract by Kliem and Wiemeyer (2010) analysed the effects of traditional balance based training verse Wii Fit in a group of 22 healthy young adults with a mean age of (47.6 yrs; *SD* = 13.1). Participants were randomised into the two groups and took part in three exercise sessions per week over three weeks (9 in total). Balance was assessed using the SEBT the same as Brumles et al., (2008) and Fitzgerald et al., (2010), no static balance was measured. A set of ball handling tests, two video game tests and dynamic balance were also assessed at baseline and post-test, however due to only an abstract been available it is difficult to scrutinise the methodology without a full paper. A psychological questionnaire was also assessed analysing various psychometric properties including mood state, self-efficacy, physical activity enjoyment, flow and subjective experience. Results showed similar to Brumles et al., (20080 in that the traditional exercise group had significant improvements in the SEBT and also ball handling tests. The exergaming group showed significant improvement in one of the game tests (ski slalom, p = 0.035) however, improvements would have been expected in the exergame group due to having played the games for 3 week, likewise the results from the SEBT favoured the traditional group due to the training. These results question the suitability of the outcome measures, as there is a source of bias with the results, in that both the exergaming and traditional exercise groups trained specifically towards outcome measures. Both groups showed statistically significant improvements over time in four of the balance measures. Psychological results showed no within or between group differences occurring.

2.15 Summary

The results from the systematic review indicate the potential use of exergaming for balance training in young healthy adults. However, more work is needed to establish the true effect of exergaming over traditional based exercise with no virtual reality environment. No current research has explored the effects of exergaming versus mirror-matched exercise on postural sway. It remains unclear the true effect of exergaming as a means of balance training in

healthy young adults. As previous studies such as Brumles et al., (2008) used a traditional exercise group, however, the exercises used in this group were performed on a wobble board, which encouraged movements in the anterior- posterior, and medial- lateral direction as well as practicing of the star balance test, which was one of the outcome measures used, therefore questioning the true effectiveness of the exergames. Likewise Vernadakis et al., (2012) used a wobble based board and a mini trampoline to compare against a participants playing on the Wii balance board, which required different movements and proprioception, (especially on the trampoline). To date, no studies have looked at exergaming versus mirror-matched exercises. As previously literature has compared exergaming to standard balance based exercises such as the star excursion balance test (SEBT) that do not replicate the movements in the exergame and are somewhat misrepresentative to compare them directly as "balance training". Therefore, there was a need to implement mirror-matched exercise versus exergaming in order to understand the potential for balance training in young healthy non-active and active adults. Randomised controlled trials (RCTs) offer the most robust study design and were therefore implemented in both studies.

2.16 <u>Physiological cost of exergaming</u>

The main difference between exergaming and traditional sedentary gaming is the incorporation of exercise into the gaming environment. Although both studies evaluated the effects of exergaming versus mirror-matched exercise on balance as a physiological outcome measure, the physiological cost of exergaming should also be explored as a tertiary aim in young active adults. Using heart rate (HR) data will give an objective measure of physiological cost of exergaming and measuring rate of perceived exertion (Borg, 1982) will give a subjective opinion of the exercise intensity. Previous literature has analysed the effects of exergaming to sedentary gaming using the Nintendo Wii (Lanningham-Foster et al., 2009; O'Donovan & Hussey 2012) and more recently comparing the Nintendo Wii against the XBOX Kinect (0'Donovan et al., 2012) and shown the potential physiological increase in energy expenditure (increased HR). Yet, to date, no study has compared

exergaming to mirror-matched exercise. Heart rate and RPE (Borg, 1982) were measured in study 2 only, as this was used as a ramp protocol to increase the duration and intensity of exercise over a 4-week period in healthy active adults. No HR and RPE data were measured in study 1 as this study primarily focused on the acceptance of technology and gaming level was kept at a low intensity due to the participants being non-active adults.

2.17 Aims of Thesis

2.17.1   Research Question

Does exergaming training have an effect on levels of acceptance, flow and postural control compared to mirror-matched exercise in young healthy non-active and young healthy active adults.

Study Aims

1) To compare participants' acceptance (behavioural intention) and flow experience (absorption in the activity) between exercising using an exergaming environment versus mirror-matched exercise.

2) To compare the effects of exergaming based training versus mirror-matched exercise on postural control during static standing with eyes open.

3) To compare the biometric intensity of exergaming versus mirror-matched exercise (HR/RPE).

4) To explore the relative contribution of components of the unified theory of technology acceptance and use of technology (UTAUT) on behavioural intention.

Study 1: A randomised controlled trial of non-active Adult's acceptance (behavioural intention) and flow experience (absorption in the activity) of exercising in: an exergaming environment (IREX™) or a mirror-matched exercise. Including an investigation of the XBUS™ system as a measure of postural control.

2.18 <u>Aims</u>

The primary aims were to;

1) To compare participants' acceptance (behavioural intention) of a two week exercise programme undertaken in either:

An exergaming environment IREX™, (Interactive Rehabilitation and Exercise system, a video-capture gaming environment), or

Mirror- matched exercise

2) To compare participants' flow experience (absorption in the activity) of a two week exercise programme undertaken in either:

An exergaming environment IREX™, (Interactive Rehabilitation and Exercise system, a video-capture gaming environment), or

Mirror- matched exercise.

2.18.1 Subsidiary Aims

To compare the effects of exergaming based training versus mirror-matched exercise on postural control.

2.18.2 Principal Aim: Hypotheses

Null hypothesis;

Compared to mirror-matched exercise there will not be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

Alternative hypothesis;

Compared to mirror-matched exercise there will be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

Null hypothesis;

Compared to mirror-matched exercise there will not be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

Alternative hypothesis;

Compared to mirror-matched exercise there will be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

2.18.3 Subsidiary Aim 1, Hypotheses

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in bipedal measures of postural sway.

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in bipedal measures of postural sway.

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

Study 2: A randomised controlled trial of physically active healthy Adult's acceptance (behavioural intention), flow experience (absorption in the activity) and postural control (before and after), exercising in: an exergaming environment (XBOX Kinect™) or mirror-matched exercise.

2.19 Aims

The primary aims were to;

1) To compare participants' acceptance (behavioural intention) of a two week exercise programme undertaken in either:

An exergaming environment XBOX Kinect™, or

Mirror- matched exercise

2) To compare participants' flow experience (absorption in the activity) of a two week exercise programme undertaken in either:

An exergaming environment XBOX Kinect™, or

Mirror -matched exercise

2.19.1   Subsidiary Aims

1) To compare the effects of exergaming based training versus mirror-matched exercise on postural control.

2) To compare the biometric intensity of exergaming versus mirror-matched exercise (HR/RPE).

2.19.2 Principal Aim: Hypotheses

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

2.19.3 Subsidiary Aim 1, Hypotheses

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

2.19.4 Subsidiary Aim 2, Hypothesis

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming for average heart rate (HR).

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming for average heart rate (HR).

Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming for rate of perceived exertion (BORG RPE).

Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming for rate of perceived exertion (BORG RPE).

3. REVIEW OF MEASUREMENT TECHNIQUES

3.1 Introduction

This chapter will critically review and appraise the measurement techniques that will be used during the course of the thesis. The first part of the chapter will explore the justification of using psychological measures using the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) and Flow State Scale (FSS) (Jackson and Marsh, 1996) questionnaires. The second part of the chapter will give justification for using the Kistler™ force plates, and XBUS™ system will firstly be discussed. The type of exergaming systems used in the thesis will also be discussed in this chapter.

3.2 Psychological analysis of measurement techniques for Technology Acceptance and flow

3.2.1 UTAUT Explained

Technology acceptance was analysed through a formatted version of Venkatesh *et al.,* (2003) questionnaire based upon the *Unified Theory of Acceptance and Use of Technology (UTAUT) (see appendix 3).* The UTAUT is sub divided into performance expectancy (PE), effort expectancy (EE), social influences (SI), facilitating conditions (FC), self- efficacy (SE) and behaviour intention (BI). This model is based upon people's perceptions of technology and how they facilitate behaviour. The UTAUT was designed in order to develop a unified model acceptable for analysing technology acceptance and use in the information technology field by incorporating 8 previous models which include; the theory of reasoned action (TRA) (Fishbein & Ajzen, 1975), the technology acceptance model (TAM) (Davis, 1989), the motivational model (MM) (Davis, Bagozzi, & Warshaw, 1992), the theory model of planned behavior (TPB) (Ajzen, 1991), a model combining the technology acceptance model and the theory of planned behaviour (C-TAM-TPB) (Taylor & Todd, 1995a), the model of PC utilization (MPCU) (Thompson, Higgins, & Howell, 1991), the innovation diffusion theory (IDT) (Tornatzky & Klien, 1982;Moore & Benbasat, 1991;1996), and the social cognitive

theory (SCT) (Bandura, 1986; Compeau & Higgins, 1995). Previously UTAUT has been used in the information technology (IT) world with researchers using the model to assess people's acceptance and behavioural intention to use new information technology systems, (Adams, Nelson, & Todd, 1992; Venkatesh & Davis, 2000; Venkatesh & Morris, 2000). The use of technology acceptance applied to exergaming is a new concept in research, interestingly, it analyses peoples behavioural intentions to use the exergaming system and the potential to use the system in the future for exercise and enjoyment purposes. The shift towards exercising in a virtual environment has initiated the cross over into the exercise world allowing a novel aspect of acceptance to be explored in a different research field. The questionnaire was modified for both the exergaming group and the normal exercise group. Existing research has demonstrated that important variables that predict technology acceptance (in terms of intention to use a particular technology for a particular purpose) include performance expectancy, effort expectancy and social influences.

3.2.2   Reliability of UTAUT

Venkatesh *et al.,* (2003) analysed the validity and reliability of the UTAUT model and found that all constructs of behavioural intention were reliable with internal consistency levels above 0.70. Performance expectancy can out as the best predictor of BI during the data collected over three studies to validate the use of the UTAUT. The results confirmed that the UTAUT model was able to account for 70% of variance (R^2) in respect to intention to use a system, which is higher than any of the original 8 models which the UTAUT comprises of. El-Gayar et al., (2011) compared the reliability of each subscale of the UTAUT when students acceptance of tablet PC's. Each variable was assessed (PE, EE, FC, SI, and BI) for construct validity (Cronbach, 1951). The results showed all variables were reliable as scores exceeded 0.70 which were deemed to be reliable.

Other studies which have applied the UTUAT have shown good reliability between the variables. Wang and Shih (2009) reported excellent levels of reliability for PE, EE and SI all

above 0.9 composite reliability. AL-Harby et al., (2010) reported Cronbachs alpha (α) all above the acceptance level of 0.70 for each UTAUT variable (PE, EE, SI, FC, SE and BI) with PE reported as the most reliable measure of α =0.89. Marchewka, Liu & Kostiwa (2007) found that PE, EE, SI and BI all had excellent reliability with Cronbachs alpha (α) over 0.70 and BI with and alpha of 0.99. However, FC and SE fell well below the acceptable level and the reliability was therefore questioned. No details of applying correction factors were mentioned in the investigation and FC and SE were still included in the analysis despite low reliability within the respective measures. AlAwadhi and Morris (2008) found that PE, EE and FC were reliable measures with Cronbachs alpha (α) over the acceptable level of 0.70, however BI fell underneath this level at 0.68 but was included in the analysis due to its closeness to 0.70. Peer influences were also assessed for reliability however, α = 0.13 was found, despite this low reliability it was still included in the analysis as it is reported as being consistently low according to AlAwadhi and Morris (2008).

The use of the UTAUT appears to show good levels of validity and reliability in respect to analysing intention to use a system. The UTAUT is novel to exergaming and has to the author's knowledge not being applied to exergaming. Within exergaming it is key to have a system which is going to be used in the future whether it is from a physical fitness perspective to reduce levels of sedentary lifestyle or whether it is in respect to interactive rehabilitation. The use of exergaming needs to be enjoyable in order to increase intention to use.

3.3   Reliability of Flow State Scale (FSS)

The Flow State Scale (FSS) was specifically designed for analysing immersion in physical activity (Jackson, Kimiecik, Ford, & Marsh, 1998; Jackson & Marsh, 1996). The FSS has shown good reliability with Chronbachs alpha (α) coefficient scores ranging from 0.81 to 0.86 (Jackson and Marsh, 1996); 0.72-0.91 Jackson *et al.,* (1992); Vlachopoulos, Karageorghis,

and Terry (2000) found reliability of the FSS α ranging between 0.65 to 0.84 for aerobic exercise and alpha coefficients of 0.91 were found in Bakker *et al.,* (2012).

An exergaming flow state questionnaire was developed by Lai et al., (2012) which consisted of a 74 item questionnaire with multiple questions for each of the 9 dimensions of flow. The Chronbachs alpha showed good reliability on a whole for the questionnaire with an α of 0.97 and α for the nine dimensions ranging from 0.74- 0.92. However, as we were assessing both exergaming and traditional exercise conditions it was felt relevant to use the Jackson and Marsh (1996) questionnaire in the current thesis, in order to make our results comparable.

The flow state scale has shown good levels of internal consistency through various studies, and is deemed a reliable scale to measure levels of immersion.

3.3.1   Summary of the questionnaire reliability

Both the UTAUT (Venkatesh et al., 2003) and Flow State Questionnaire (Jackson and Marsh 1996) show good reliability for within measurement subscales, independently. Both questionnaires will be used in the thesis to assess; technology acceptance and in particular behavioural intention (UTAUT) and levels of flow (FSS) when comparing exergaming to mirror matched gym based exercise with no virtual stimuli.

3.4 Postural Stability

Postural stability can be defined as the ability of an individual to maintain their centre of mass (COM) or equilibrium within a base of support, (Shumway-Cook, & Woollacott, 1995). In order to effectively measure postural stability there are three main approaches which are used (Horak, 1997). A functional approach includes techniques and tests to assess functional daily living abilities (Shumway-Cook, & Woollacott, 1995) examples of such tests are the functional reach test which is aimed to get participants to reach as far forward as they can so they are towards the edge of their base of support (Duncan *et al.,* 1990), this test has high intra- rater reliability of interclass correlation coefficient (ICC) of 0.98. Other functional assessments of balance include the fall risk index and the Berg Balance test (Berg *et al.,* 1992) the latter is commonly used in clinical populations with high inter-rater reliability reported at 98% (Horak, 1997). The next approach is a systems approach can be used in clinical practice and assessment to determine pathological causes which contribute to a balance deficit. In a systems approach three main categories are used to try to distinguish the possible cause of balance deficits, those are; biomechanical, motor condition and sensory organization constraints. Lastly the third approach of assessing postural sway comes in the form of quantitative posturography using biomechanical instrumentation to assess changes in postural sway (Horak, 1997). Such analysis includes methods such as three – dimensional (3D) video analysis combined with force plates (Newton and Neal, 1994), surface electromyography, and more commonly used is static force platforms which allow the participants centre of pressure (CoP) to be calculated automatically whilst standing on the force platforms, the use of force platforms for the assessment of postural sway can detect minimal movements during a range of tasks usually to the nearest millimetre (mm).

In the current thesis, balance performance was measured using a single, static quantitative posturography (force platform). The justification for using the force platform technique is that

is it widely used in the assessment of postural control with good test- re- test reliability (Benvenuti *et al.,* 1999), and allows an objective tracking of postural control. The subject population in both studies of the thesis are healthy adults therefore it seemed logical to use a quantitative posturography approach as a functional and systems approach are more appropriately used in clinical conditions.

3.4.1   Kistler™ Force Plate

In the past CoP was measured with mechanical or magnetic recording devices connected to the waist (Dornan, Fernie, & Holliday, 1978; Lord, Clark, & Webster, 1991), however due to technological advances force plates are now commonly used in practice (Błaszczyk, 2009; Raymakers, Samson Verhaar, 2005) enabling CoP for the whole body to be quantified and measured as opposed to one segment (waist). Force plates are commonly used in biomechanical practice for the assessment of postural control and gait analysis which has been used since the 1970's to assess postural control (Palmieri *et al.,* 2002). This type of assessment can be widely used in both normal and clinical populations (Ekdahl *et al.,* 1989). Force plates can either be portable or imbedded within the ground of the laboratory, the latter techniques is good for the assessment of gait as it allows a more normal gait pattern to occur. Force plates are considered a "gold standard" method for the assessment of balance in laboratory based settings (Haas & Burden, 2000) and this current thesis used a Kistler™ portable force platform for both studies in order to assess postural sway. The force platform comprises of triaxial piezoelectric force transducers embedded within each of its four corners allowing forces on the surface of the plate to be measured. When standing upright on the force plate ground reaction forces (GRF) occur in three planes of motion; Fy is anterior- posterior force, Fx is the medial- lateral force, and Fz is the vertical ground reaction force commonly known as the centre of pressure (CoP), (Goldie *et al.,* 1989). For the current thesis the participants will be asked to stand on the force plate and face the wall directly in front of them at all times, this ensures that the orientation of the force plate and planes remain constant throughout the testing. When standing on the force plate the person's body

weight acts vertically on the force plate which forces the piezoelectric crystals to become electrically charged, thus allowing movement patterns to be captured and visually displayed. When standing on the force plate during static assessments of balance, participants should stand as central to the plate as they can as when participants stand closer to any of the four corners of the force plate then the accuracy of the readings can be changed. Bobbert and Schamhardt (1990) analysed the accuracy of the Kistler™ force plate and found that the average error was 3.5 mm in the *y* axis (AP) and 6.3mm in the *x* axis (ML) direction, however these errors changed considerably when participants get closer to the outside of the plate, especially on any of the outer four corners. Middleton et al., (1999) concur with these results and found that there was a 2:1 ratio in errors for the y axis compared to the x axis. It is also believed that errors increase when there is unilateral loading in comparison to bipedal loading.

When both feet are in contact with the force plate the area between feet is where CoP is located (Middleton *et al.,* 1999). When assessing bipedal standing two methods can be used; 1) use one force plate or 2) use 2 separate force plates and assess each foot's CoP separately. In the current study only one force plate will be used to get an overall CoP measurement as opposed to each foot for the assessment of both bipedal and unipedal postural sway using a portable Kistler™ force plate. Participants will be asked to stand facing forwards at all times so that the orientation of the force plate remains constant. With the use of a single force plate displacements in the anterior-posterior (AP), medial –lateral (ML) and Centre of Pressure velocity (CoP) displacement can all be calculated. Bioware software accompanies the Kistler™ force plate and gives a visual representation of the sway path during different activities and gives CoP displacements for AP and ML displacements.

Other force plates were considered during the testing such as the Nintendo Wii™ balance board (WBB), which has previously shown good reliability (Clark *et al.,* 2010) between other force plates (ICC= 0.77-0.89). Despite the high validity of the WBB it should be noted that a limitation in the device over more clinically available force plates is that the WBB has an

inability to assess horizontal axes which is important for CoP equation. Ultimately the Kistler™ force plate was chosen for its good reliability and has also been used widely in the research field for the assessment of postural control (Raymakers *et al.,* 2005; Hatton *et al.,* 2011). Therefore, postural sway data will be collected from one static Kistler™ force platform (Model 9286AA, Kistler, Alton, UK).

3.4.2   Sampling Rate

When recording postural sway data, sampling rates should be pre-defined before testing, if data is sampled at too low of a frequency, this can lead to substantial loss of information. Currently there are no guidelines for the optimal sampling rate. Therefore in the current thesis a 1000Hz will be used to minimise the risk of losing important sway data and is commonly used in practice (Hatton *et al.,* 2011; Nejc et al., 2010).

3.5   Centre of Pressure

Centre of Pressure (CoP) is the point location of the vertical ground reaction force vector. It represents weighted averages of pressures distributed over the surface of the area when feet are in contact with the ground. In order to keep the COM within the base of support this requires the CoP to continuously move around the COM (Shumway-Cook & Woollacott 2007). Centre of pressure (CoP) is commonly measured using a force plate to measure the magnitude of movement, (Piirtola & Era 2006)

It is established in research that when CoP movement increases this causes a decrease in postural stability. The presence of an injury such as chronic ankle strain have diminished postural stability especially in single leg stance, (Evans et al., 2004), and the elderly are commonly referred to in research as having poor postural stability due to deterioration in the sensory motor function (Priplata et al., 2003), or neuromuscular systems and as a result have an increased risk of falling.

3.5.1 Centre of Mass

Centre of Mass (COM) "a point that is the centre of the total body mass, which is determined by findings the weighted average of the COM of each body segment" (Shumway-Cook & Woollacott 2007). The vertical projection of the COM is the centre of gravity (COG) and is defined by the direction of gravity (Winter 2005). The terms COM and COG can be used interchangeably when relating to postural stability, (Kreighbaum & Barthels, 1990; Winter, 1995; Shumway-Cook & Woollacott 2007). It has been estimated that COM can be found at the S2 vertebral level in normal upright standing, (Gard, Miff &, Kuo 2004).

3.6 Postural Sway Parameters

When trying to maintain postural stability, centre of pressure (CoP) movements occur in all directions. Using a force plate we can quantify the amplitude of movements in the anterior-posterior (AP) direction (front and back) and medial –lateral (ML), (side to side) directions during quite standing, (Shumway-Cook and Woollacott, 1995). The magnitude of CoP movement and velocity provides a reliable measure of balance ability (LeClair & Riach 1996; Riach & Starkes 1994). In the current thesis, CoP amplitude and velocity will be reported during quite stance.

3.6.1 AP and ML Range

The amplitude of CoP during quiet stance can be quantified in terms of the amount of sway in the AP or ML direction. By using AP and ML range this gives an objective measure of the maximum - minimum (mm) CoP movements and extremities in sway path in each direction. Pinsault and Vuillerme (2009) analysed the test- retest reliability of centre of foot pressure measures during quite standing with eyes closed. They found that AP and ML range had excellent test- re test reliability when assessing postural sway for 30 seconds. However, it should be noted that this was during eyes closed only, and no eyes open data was generated. Within the literature it is reported that ML displacements are greater in elderly people than young individuals (Raymakers et al., 2005). It should be worth noting that

despite the plausibility of assessing the maximum- minimum amplitude during quite stance, there can be variance occurring between trials and also between subjects (Palmieri *et al.,* 2002). The variation in the range amplitude can be attributed to high variance within or between sessions this may occur during a static trial when momentarily a subject loses balance due to loss of concentration which can cause large variance to occur in the amplitude. However, this variance can be minimised by performing multiple trials of standing balance as opposed to a single trial (Ruhe *et al.,* 2010).

Pinsault and Vuillerme (2009) explored the test- re test reliability of CoP measures during quite standing using 10 healthy subjects (five males and five and females, mean age ± 1 SD 24.6 (2.5) years). Range data was collected in the AP (mm) and ML (mm) directions and CoP mean velocity (mm.s^{-1}) as well as surface area and CoP maximal velocity (mm.s^{-1}). Test re-test design was used to assess the reliability using inter class correlation coefficients (ICC's) and Bland and Altmans (1986) limits of agreement. Results showed that when only one trial was used ICC's were only excellent > 0.75 for velocity, maximal velocity, AP velocity and AP Max velocity. Whereas 3 or more trials gained excellent reliability (>0.75) in all measures of postural sway. However, a limitation of this design was that this was conducted with eyes closed and therefore results are difficult to compare to eyes open trials, and more variations may occur in relation to the reliability of the measures, never the less amplitude range data in AP and ML directions appear a useful measure of postural control with a combination of other parameters.

3.6.2 **AP and ML Standard Deviation**

AP and ML Standard deviation (SD) can be known as the "distribution of CoP displacements over time" (Baloh *et al.,* 1998; Geurts *et al.,* 1993). The SD is commonly used as a measure of CoP in the AP and ML direction during quite standing (Le Clair and Riach 1996; Vuillerme et al., 2008). Le Clair and Riach (1996) assessed the parameters of AP SD and ML SD during the assessment of postural control in a group of healthy adults (n=12, aged 19-32

years). Results found that SD in the lateral and AP direction increased with time, with 60s showing the highest variability. However, Riach and Starkes (1993) disagree and suggest that variability in AP and ML SD decrease with longer duration trials as there is a tendency for subjects to become more "settled in" or stable with time. Despite differences occurring in results in respect to time and the amount of movement in CoP SD Le Clair and Riach (1996) acknowledge that CoP SD parameters are reliable measure of postural control. Palmieri *et al.* (2002) concur with Le Clair and Riach (1996) in that a combination of parameters such as AP SD, MLSD and CoP Velocity parameters are valuable measures to be used in assessing minimum detectable changes in postural control.

3.6.3   CoP Velocity

Centre of pressure velocity represents a time dependant variable for assessing postural control. Simoneau et al., (2008) described CoP velocity as the total distance covered by CoP (total sway path) divided by the set sampling rate during the assessment of postural control. CoP velocity has been well documented as a standard method of assessing postural control in research (Baloh et al., 1998; Hunter & Hoffman 2001) as well as good reliability for between sessions double limb stance (R =0.84), (Le Clair and Riach,1996). The use of CoP velocity allows researchers the ability to assess the magnitude of movement patterns during postural control, in essence a decrease in CoP Velocity (total movement) results in improvements in postural control and an increase in CoP Velocity means postural control has got worse, this can be used in biomechanical and clinical assessments of postural control in healthy and injured athletes.

In this current thesis AP SD, AP range, ML SD, ML range and CoP velocity will be used to assess postural control during quiet standing balance during bipedal and unipedal stance.

3.6.4   Recommended number of trials for the assessment of static postural control

With regards to the number of balance assessments which should be used there is conflicting literature which would suggest anything from one trial can be reliable (Le Clair

and Riach 1996) to multiple trials (Tarantola, Nardone, Tacchini and Schieppati, 1997). A systematic review on bipedal test- re test reliability by Ruhe et al., (2010) suggested that 3-5 trials are deemed acceptable for the assessment of postural control.

In the current thesis 3 trials of standing balance were assessed for both bipedal and unipedal standing as this is supported by a number of authors assessing standing balance (Carpenter et al., 2001; Hrysomallis et al., 2006; Haidan et al., 2008; Harringe et al., 2008; Hatton et al., 2009; and Ruhe et al., 2010).

3.7   Sampling Duration

The time of sampling duration during posturography has been a constant debate in literature in respect to yielding the most reliable time duration for the assessment of postural sway during static standing. Variations can change due to difference in balance disorders, age and for eyes open and eyes closed and between bipedal (two legged) and unipedal (one legged stance). Durations of standing balance tasks have been reported in literature to range from 10 – 60seconds (Letz and Gerr 1995; Bauer et al., 2008; Raymakers *et al.,* 2005) excluding clinical trials which take fatigue into account and thus trials will alter in minutes not seconds. Doyle et al., (2007) found that 5 trials of 60 seconds of duration to show acceptable levels of reliability with eyes open, and 30 second durations with eyes closed. Doyle et al., (2007), however, discusses that the implications of 60 seconds duration may be too difficult for different clinical and aging populations. Carpenter et al., (2001) partly concurred with Doyle et al., (2007) when analysing the effect of sampling duration on the reliability of centre of pressure measures in upright standing in healthy adults. Participants performed standing balance tasks for 15, 30, 60 and 120 seconds durations. Results found AP and ML reliability increased with length in sampling duration with 15 seconds showing the lowest reliability and 120 seconds showing the highest, with 30 and 60 seconds showing moderate reliability. Although 30 seconds showed moderate reliability in CoP outcomes, the recommendations of reliability was believed to be at least 60 seconds in duration, again depending on the

participant's capabilities. Although research has indicated the potential for longer durations of standing balance there is still debate which indicates 20-30 seconds is required for reliable standing balance. Le Clair and Riach (1996) analysed the optimal duration for postural stability measures using twenty five participant (13 female 12 male) aged between 19-32 years old. Four stances were analysed: eyes open legs together, eyes closed legs together, Ronnberg stance (heel to toe) in eyes open and eyes closed. Each participant repeated the four trials over five time scales (10s, 20s, 30s, 45s, and 60s). The optimum test- re- test reliability was between 20s and 30s trials and 10s trials showed to be the least reliable of all of the time durations. Pinsault & Vuillerme (2009) analysed the optimum test-retest reliability of number of trials and standing duration in young healthy adults. Participants performed 10 trials of 30 second bipedal balance with eyes closed and found that when only one trial was used only measures in the AP direction could be accounted for as reliable based on interclass correlation coefficient scores to be over 0.75, however when three trials were used all measures of CoP showed ICC's of >0.75 showing excellent test-retest reliability for 3 trials of 30second durations which concur with Le Clair and Riach (1996) findings. In the current thesis a test time of 30s was chosen as this could then be replicated in future practice with other non-healthy populations and the elderly, where longer durations of standing balance may be too difficult.

3.8   Factors affecting data acquisition

3.8.1   Foot Positioning

The standardisation of foot placement during bipedal standing is often a debatable aspect of postural sway literature with a variety of techniques being used in research. Techniques can range from having feet shoulder width apart in a natural stance, Romberg stance where feet are heel and toe in line (Le Clair and Riach 1996), International Society of Posturography (ISP) recommend heel to heel distance of 30° angle between medial borders of the feet with the heels together (Pinsualt and Veuillerme, 2009) and fixed positions standing such as Raymakers et al., (2005) and Santos et al., (2008) who got subjects to stand with feet

parallel on each side of a 4cm T shaped separator which was fixed to the force plate. Although various methods have been assessed, they offer the possibility of having an un-natural stance; having pre-defined foot positioning may in turn alter CoP as opposed to getting participants to stand naturally on the force plate with feet shoulder width apart. In the current thesis participants were asked to stand in a comfortable position with feet shoulder width apart as this was deemed the most natural position (Panzer et al., 1995, Maki, Holliday, and Topper, 1991).

3.8.2   Head Position

When performing static balance tests participants are usually required to look straight ahead during quite stance (Keshner and Dhaher 2008), the use of a visual target that is positioned at eye levels can often be used in testing protocols in order to standardise head position during quite standing and maintain focus of looking straight ahead to minimise movements at the head, (Lafond et al., 2004; Raymakers *et al.,* 2005; Brumels *et al.,* 2008; Pinsault and Vuillerme 2008; Santos et al., 2008; Hatton et al., 2011). In the current thesis head position will be standardised by getting all participants to focus on a black circle positioned directly in front of them at eye level.

3.8.3   Upper Body Position

During the current thesis no upper body standardisation was made as participants were asked to stand as still as possible which required the trunk to be in a vertical position. Arm position during standing balance was standardized in that participants were required to have their arms at the side as this was deemed as a natural standing position as opposed to having arms in front or to the back, (Ruhe et al., 2010) This natural standing position with the arms by the sides is common in postural sway literature (Le Clair and Riach 1996; Lafond et al., 2004; Pinsault and Vuillerme 2009 and Pluchino *et al.,* 2012).

3.8.4 Lower Body Position

When assessing postural sway using posturography participants should be barefooted throughout all assessments of balance in order to add to the reliability of the data. During unipedal stance it was opted for participant's knee and hip to be self-selected in order to mimic a more natural standing position for the assessment of postural control (Hoffman and Payne, 1995).

3.8.5 Stand still verse stand quietly

The variation in task demands from the researcher (s) can influence the results on postural sway outcomes according to Zok et al., (2008). Zok et al., (2008) analysed variations in different instructions for standing balance and found that when participants were instructed to "stand as still as possible" this demonstrated a higher consistency rate in their CoP displacements measures during the balance trials compared to participants who were instructed to "stand quietly". Raymakers *et al.*, (2005) and Ruhe *et al.,* (2010) also support this notion that when assessing standing balance the instructions should ask the participants to "stand as still as possible looking straight ahead". Therefore in the current thesis participants will be instructed to stand as still as possible during the course of the standing balance tasks.

3.9 Postural Control Measurement Using Inertial Sensors (XSENS™)

3.9.1 Background of inertial sensors

Inertial sensors are used in human movement science to track movements using accelerometers, magnetometers and gyroscopes or a combination of systems to accurately track movements occurring in a non-invasive manor (Saber-Sheikh et al., 2010). Accelerometers are responsible for tracking acceleration of movements, magnetometers are responsible for measuring the strength or direction of a magnetic field and gyroscopes measure the orientation of the device. The application of accelerometers and gyroscopes used together has shown good reliability and accuracy in tracking human movement (Luinge

et al., 1999; Luinge and Veltink, 2005; Sabatini et al., 2005; Boonstra et al., 2006). Yet the combination of applying accelerometers, gyroscopes and magnetometers is a relatively new application to human movement research in developing micro electro- mechanical systems (MEMS) inertial sensors which offer a combination of all three. The inertial sensors have an advantage over accelerometers or gyroscopes separately as they offer more in depth analysis regarding the rate of movement (accelerometer), degree of movement (gyroscope) and position relative to the earth's magnetic field (magnetometers).

3.9.2 <u>XSENS™ motion capture system</u>

XSENS™ motion capture (www.xsens.com) offer a range of micro electro- mechanical systems (MEMS) inertial sensors to track human movement. One of the most popular systems created by XSENS™ is the XBUS™ system which allows tracking up to 6 inertial sensors at a time for human movement. The thesis will use the XBUS™ system to track movement of the lower back and posterior aspect of the head during standing balance using two inertial sensors designed by XSENS™. These inertial sensors are lightweight and incorporate 3D tri- axial gyroscopes, tri- axial accelerometers and tri- axial magnetometer which are reported to provide drift-free motion data (Saber-Sheikh et al., 2010). The use of MEMS inertial sensors have developed rapidly in human movement science (Zijlstra & Aminian 2007; Mathie et al., 2004; Wong, Wong and Lo 2007; Altun & Barshan 2009; Sabatini 2006), sport science (Ermes et al., 2008) and the animation industry (Shiratori, and Hodgins 2008). The use of MEMS inertial sensors for human movement such as gait analysis offers a novel aspect for both biomechanical and clinical perspectives in that originally gait would be observed using 3D motion capture systems such as Vicon™ which requires a full body markers set and a laboratory that has 8-10 infra-red cameras and is therefore limited to laboratory testing and are less convenient (Altun et al, 2010) whereas MEMS inertial sensors are mainly Bluetooth enabled which means capture can be done outside of the laboratory and are not limited to a restricted capture space such as Vicon™. Another advantage over 3D motion capture is that inertial sensors are becoming relatively

inexpensive and more commercially available. Theis et al., (2007) conducted an investigation comparing the reliability of 3D motion capture (Vicon™) compared to two inertial sensors XSENS™ (XSENS, Xsens Technologies B. V., Enschede, Netherlands) and Kionix™ (Kionix Inc., Ithaca, New York, USA) during reach and grasp tests. The results showed that for the upper limb positions reliability was excellent between XSENS™ and Vicon™ in the x (r = 0.99), y (r = 0.99) and z (r = 0.95) directions and similar results for lower arm position in the x (r = 0.99), y (r = 0.99) and z (r = 0.99) directions. Interestingly, the correlation between the inertial sensors also showed excellent correlations for the upper arm in the x (r = 0.99), y (r = 0.99) and z (r = 0.99) and similar results for the lower arm position x (r= 1.0), y (r = 0.99) and z (r = 0.99). The results indicate the potential for using inertial sensors as a method of analysing movement.

3.9.3 <u>MEMS Inertial sensors and Postural control</u>

Static posturography widely assesses sway through centre of pressure occurring at the foot level which is in contact with the force plate during sway assessments (Le Clair and Riach 1996; Pinsualt and Veuillerme, 2009, Hatton et al., 2011).

Recently, however, Mancini and Horak (2011) acknowledged that accelerometers and gyroscopes placed on the trunk or head offer alternative methods to assess postural control. Mayagoitia et al., (2002) analysed standing balance tests using a triaxial accelerometer compared to an AMTI™ force platform, the accelerometer was placed on a belt and attached to the subject waist. Various balance tasks where then performed on the force platform including static eyes open and eyes closed double limb stance. The results showed that the accelerometer was able to distinguish the difference between each postural control test equally or better than the force plate. Whitney et al., (2011) compared accelerometry and centre of pressure measures during computerized dynamic posturography. Acceleration was measured at the pelvis using a custom made belt with accelerometers attached, in 81 subjects aged 19 to 85 years old (47.8 ± 21.2 years; height 66.3 ± 3.7inches). Postural

control was assessed using CoP. Results showed that postural control and accelerometry were correlated well when performing postural sway tasks. Test re-test reliability showed good to excellent results for accelerometry data and had higher reliability than CoP in some measures of postural sway (eyes open solid surface, sway referenced support surface with eyes open, sway referenced support surface with eyes closed). The results from both studies indicate the potential use of accelerometry for assessing postural control. Despite the positive result more research is needed to truly assess the application of accelerometry for an alternative method of assessing postural control. Having only acceleration data may not offer as robust of method of postural control analysis as an inertial sensor would. Including gyroscopes and magnetometers would give positional and rotational data as well as acceleration which would be useful in the assessment of postural control to see the relative distance moved during a time specific task.

Mancini and Horak (2011) believe that accelerometers or gyroscopes placed on the lower back or thigh can offer postural sway data similar to that collected on a force plate. Mancini et al, (2009) also concur in that inertial sensors can be used as a new method to assess postural sway. More specifically Mancini et al., (2012) used XSENS™ MEMS inertial sensors to measure trunk sway in step initiation tasks in healthy controls and Parkinson's Disease and showed that inertial sensors could offer an alternative approach to measuring postural control. The application of this method for assessing postural sway offers a novel approach which takes into account upper body movements. In the current thesis, MEMS inertial sensors (XBUS™ System) will be used to analyses postural control of the upper body during quite standing in double (bipedal) and single (unipedal) standing.

3.9.4 <u>XSENS™ MEMS Inertial Sensors</u>

The MEMS inertial sensors are small in size 38 mm by 53 mm by 21 mm in size, weigh 30 g (see Figure 12).
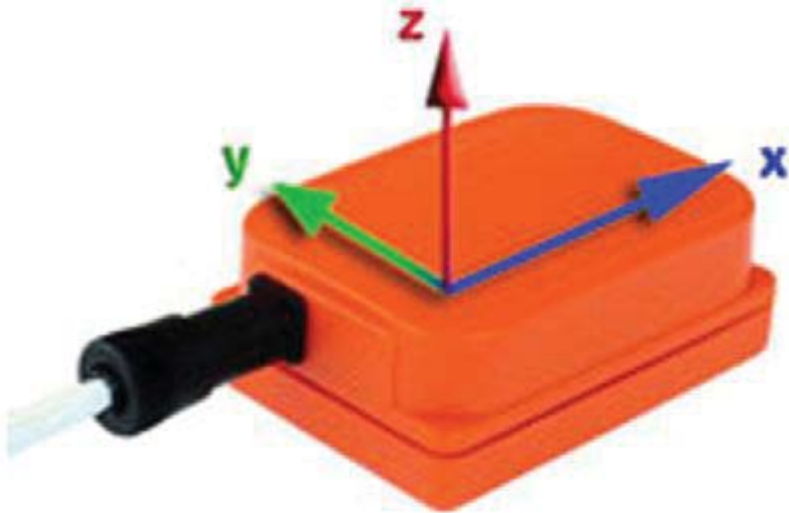
Figure 12: MEMS inertial sensor with the 3 directional outputs the device will get (reprinted from http://www.xsens.com/en/ general/mtx)

In order to track upper body movements the XBUS™ system (XSENS™ Technologies B.V., Enschede, Netherlands) was used. The XBUS™ system comprises of 6 lightweight MTX units (figure 1) and an XBUS data logger (more detailed explanation is in chapter 4). The XBUS™ system was chosen due to the lightweight system and non-invasive technique to measure upper body postural control (Mancini et al., 2009; Paulis et al., 2011). Other systems which have previously been used in research are the SwayStar™ (Balance International Innovation GmBH, Switzerland) that measures roll (side to side) and pitch (fore-aft) movements using two gyroscopes (Horlings et al., 2009; Huffman et al., 2010) or electromagnetic sensors (Flock of Birds, Ascension, Inc), (Keshner and Kenyon 2000). Ultimately the XSENS inertial sensors were chosen in the current thesis due to incorporating gyroscopes, accelerometers and magnetometer and due to the good reliability of the system.

3.10 XSENS Instrumentation

3.10.1 Reliability of Inertial Sensors

When assessing the reliability of the MEMS inertial sensors Paulis et al., (2011) analysed the test–retest and inter-rater reliability for Tardieu Scale measurements (a scale of range of motion and angle of catch) using inertial sensors for elbow flexion in people who had

strokes. Goniometers where compared against inertial sensors for the Tardieu Scale measurements in 14 stroke patients. Results showed that for inter – rater reliability the inertial sensors showed excellent reliability (ICC 0.84) compared to good (ICC 0.66) using goiniometery. Despite test re-test showed higher reliability using goiniometry (ICC 0.86) compared to (ICC 0.76) for inertial sensors both devices were rated as excellent in terms of ICC scores (Cicchetti & Sparrow, 1981).

Saber-Sheikh et al., (2010) conducted a Feasibility study using inertial sensors to assess human movement during the investigation XSENS inertial sensors were compared against an electrogoniometer system (The Fastrak system). Hip motion was analysed during normal walking in healthy subjects when wearing the electrogonimoeters and 2 inertial sensors. Results showed the XSENS™ was reliable for measuring walking gait and that a good level of agreement was displayed between both devices. The results indicate the potential of using XSENS™ inertial sensors as a reliable inertial sensor tool. XSENS™ inertial sensors offer a revolutionary way to analyse movement and postural sway, yet they are expensive (£4000 for 2 inertial sensors). The expensive nature of the systems has led to developments of smart phones incorporating inertial sensors, and gaming devices such as the Nintendo Wii™ and Sony Playstation Move™. The Nintendo Wii™ has a tri- accelerometer built in and 3 axis gyroscope built into the remote however no magnetometer is built into the system unlike the XSENS™ inertial sensors. Alternatively, the Sony PS Move has an accelerometer, a dual-axis gyroscope (x, y) and one single-axis gyroscope (z) and a magnetometer. Bai et al., (2012) analysed the reliability of the XSENS™ inertial sensor against the Wii™ remote and Sony Move for upper body movements. The results showed that the XSENS™ inertial sensor is a reliable good for assessing upper body movements with results showing error no greater than 0.3° for a static angle and reliable for a change of position within a 0.05 cm. The Sony Playstation Move™ was more comparable to the results from the XSENS™ system as with the Nintendo remote failing to have a magnetometer the measurement of rotation in three dimensions is not representable.

3.10.2 Sway parameters

When collecting postural sway data using the XBUS™ system, three directional movements are detected from the MEMS inertial sensors. During movement the sensors pick up movements in the roll (medio-lateral, ML), pitch (anterior-posterior, AP) and yaw (rotation). XSENS™ report a static accuracy of 0.5 degree (Bai et al., 2012) for roll and pitch,1 degree for yaw, and a 2 degree rms dynamic accuracy.

3.10.3 Sampling Rate

Sampling rates range in terms of inertial sensor research ranging from 50Hz (Saber-Sheikh et al., 2010; Spain et al., 2012), 60 Hz (Dinu et al., 2012) 100Hz (Paulis et al., 2011; Gonz´alez et al., 2012) and up to a maximum sampling rate of 512Hz (Altun et al., 2010). No research has previously analysed the best sampling rates using the XSENS™ inertial sensors, as this is a new area of research with regards to postural control a 120Hz sampling rate was deemed acceptable as it was expected movements would be minimal.

3.11 Outcome measures

3.11.1 Summary

Levels of technology assessment will be measured through an adapted version of the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire (Venkatesh et al., 2003) and flow will be measured through a 36-item flow state questionnaire (Jackson and Marsh, 1996).

Postural sway will be measured using a Kistler Force plate (Model 9286AA, Kistler, Alton, UK), for the assessment of quiet stance with eyes open during bipedal and unipedal standing. Sway parameters that will be measured are: AP SD, AP range, ML SD, ML range and CoP velocity (Hatton *et al.,* 2010, Raymakers *et al.,* 2005). Sway data will be collected over 30 seconds for bipedal standing (Le Clair and Riach 1996) and 15 seconds for unipedal

standing. All participants will be instructed to stand as still as possible during all postural sway trials (Zok et al., 2008; Raymakers *et al*., 2005 and Ruhe *et al.,* 2010).

Static balance was chosen as an outcome measure over dynamic balance as the reliability of dynamic testing such as hop to stabilisation have not been successful in showing good test re-test reliability (Riemann, Caggiano , Lephart, 1999; Atwater 1990; Broadstone, Westcott, & Deitz 1993) as opposed to static balance. In respect to using eyes open as opposed to eyes closed this was chosen as a measure of functional activity which could be translated into exercise and sport as the thesis was using a young healthy cohort.

To investigate upper body movements during the recording of balance outcomes neck and pelvic deflections were measured using the XBUS™ system (XSENS™ Technologies B.V., Enschede, Netherlands). This consists of, a data logger and two MEMS inertial sensors (one positioned at the neck and one on the pelvis). These record deflections (degrees) in the coronal (roll), sagittal (pitch) and transverse (yaw) planes, and the outcome measures used were the maximum peak-to-peak range in each plane during the balance trials (total movement). The XBUS™ system comprises a lightweight belt worn around the waist to which is attached a data logger (XBUS Master, W10 x L15 x H4 cm, 330g). In addition, two lightweight inertial sensors were worn – One was attached to the participant's skin at the level of the Spinous Process of the forth Lumbar Vertebrae (L4).

3.11.2 Exergaming Types

Exergaming environments can be either purpose built (IREX™) or commercially available exergames (Dance Dance Revolution™, Sony Eye Toy™, Nintendo Wii™, XBOX Kinect™). Both types of exergaming systems allow the participant the opportunity to interact with a virtual background. Whether this is through the production of their own body image on the screen (purpose built) or an avatar character (commercial). In the thesis both a purpose built and commercial exergame system was used. The IREX™ system was the purpose build exergame system which has been supported for the use in clinical populations (Weiss et al.,

2003; Brown- Rubin et al., 2005; Sveistrup et al., 2003) and was used in the first study in non-active healthy adults. This equipment was chosen because it is controller free and in order to move in the exergaming setting the participant has to move themselves, thus producing movement during the game as opposed to other exergaming systems such as the Nintendo Wii™ whereby the participant can produce movements by the flick of their wrists using a hand held controller.

In study 2 the XBOX Kinect™ was chosen as the exergaming system. The Kinect™ works of the same software as the IREX™ using gesturTek technology and infrared sensors pick up the movement of the participant allowing more movements to be utilised during the game as oppose to hand held controlled games. The Kinect™ was chosen in the second study as it use healthy active adults, and through observation of the results from the first study the IREX™ is primarily a rehabilitation exergame, and therefore the intensity of the exercise is low.

4. METHODOLOGY

Study 1: A randomised controlled trial of non-active adults acceptance (behavioural intention) and flow experience (absorption in the activity) of exercising in: an exergaming environment (IREX™) or a mirror-matched exercise. Including an investigation of the XBUS™ system as a measure of postural control.

4.1 Aims

The primary aims were to;

1) To compare participants' acceptance (behavioural intention) of a two week exercise programme undertaken in either:

An exergaming environment IREX™, (Interactive Rehabilitation and Exercise system, a video-capture gaming environment), or

Mirror- matched exercise.

2) To compare participants' flow experience (absorption in the activity) of a two week exercise programme undertaken in either:

An exergaming environment IREX™, (Interactive Rehabilitation and Exercise system, a video-capture gaming environment), or

Mirror- matched exercise.

4.1.1 Subsidiary Aims

To compare the effects of exergaming based training versus mirror-matched exercise on postural control.

4.2   Hypotheses

4.2.1   Principal Aim: Hypotheses

H_0 Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

H_1 Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

H_3 Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

H_4 Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

4.2.2   Subsidiary Aim 1, Hypotheses

H_5 Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in bipedal measures of postural sway.

Alternative hypothesis;

H_6 Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in bipedal measures of postural sway.

Null hypothesis;

H_7 Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

H_8 Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

4.3 Study Design

A randomised controlled trial with two groups and factors;

Group 1 - exergaming with the IREX™ system,

Group 2 – mirror-matched exercise

Factor 1 - between subjects, exercise group with two levels – IREX™ and mirror-matched exercise group.

Factor 2 - within-subjects, time with two levels – start (baseline) and end (post-programme).

4.4 Location and Governance

Ethical Clearance was sought from and granted by the School of Health and Social Care Research Governance and Ethics Committee at Teesside University (TU) (May 2009) (see appendix 1). The study was conducted in the Physiotherapy Research Laboratory, Constantine Building (TU).

4.5 Recruitment

An invitation email was sent via the TU Outlook system to all TU staff and research students (Appendix 2). Recruitment posters were also placed across the University (Appendix 3). People who replied were asked to read the participant information sheet (Appendix 4) and had the opportunity to ask GB any questions. Verbal and written informed consent was obtained from all those who decided to take part (Appendix 5).

4.6 Sample

Inclusion criteria: aged over 18, staff or students, able to read and write in English, leading a predominantly sedentary life style, verified by self-report (undertaking less than 30 minutes of moderate exercise most days of the week, ACSM, 2005).

Exclusion: Inability, or any doubt of ability, to give informed consent, inability to comprehend and write English, current, or history of (verified by self-report), any condition or injury which would contraindicate participation in the exercises under study, routine exerciser - defined as (by self-report) taking *'moderate aerobic activity for a minimum of 30 minutes, five days per week or vigorous aerobic activity for a minimum of 20 minutes, three days each week'* (ACSM 2005), allergy to alcohol Wipes and/or adhesive tape (self-report).

A convenience sample of 38 participants was recruited for the study (20 Females and 18 Males), participation was voluntary and no payment was given for taking part. Sample size of n=50 was initially decided upon using a priori power analysis (using G* power) to calculate the statistical power before the study. However due to issues with recruitment and time constraints only n=38 were recruited.

4.7 Instrumentation

4.7.1 Unified Theory of Acceptance and Use of Technology (UTAUT) Modified Questionnaire.

Participant's acceptance of the exercise environment was quantified as Technology Acceptance using a formatted version of Venkatesh *et al.,* (2003) questionnaire the *Unified Theory of Acceptance and Use of Technology (UTAUT) (Appendices 6&7).* The UTAUT model has previously shown good levels of reliability with internal consistency levels above 0.70 (Chronbachs Alpha scores), (Venkatesh et al., 2003; Wu et al., 2007; Marchewka, Liu & Kostiwa 2007; and AL-Harby et al., 2010).

The UTAUT is sub divided into five domains: performance expectancy (PE), effort expectancy (EE), social influences (SI), facilitating conditions (FC), and behaviour intention (BI). The questionnaire uses Likert scale responses on a 1-5 scale of agreement with the preceding statement (1 being strongly disagree and 5 being strongly agree). In this study minor changes were made to the wording of questions so they were specific to either exergaming (IREX™) or mirror-matched gym based exercise with no virtual stimuli groups *(Appendices 6&7)*.

4.7.2   Flow State Questionnaire

Absorption in the exercise activity was quantified as Flow State using the Flow State Scale questionnaire (Jackson and Marsh, 1996) (Appendix 8). Flow is defined as a state in which an individual feels totally immersed in an activity both physically and mentally and nothing else at the time seems to matter, (Csikszentmihalyi, 1990). The Flow state scale (FSS) has previously demonstrated good psychometric properties on a range of athletes (Bakker et al., 2011; Pates et al., 2003).

The Flow State Scale questionnaire consists of a 36 items grouped in 9 sub-scales: Autotelic Experience (AE), Clear Goals (CG), Challenge-Skill Balance (CB), Concentration of Task (CT), Paradox of Control (PC), Unambiguous Feedback (UF), Action-Awareness Merging (AM), Transformation of Time (TT), and Loss of Self-Consciousness (LS). This questionnaire was applied in its published format as no adaptations were needed as the questions are related to performance rather than the environment specifically.

4.7.3   Postural sway during standing:

Postural sway was quantified using a portable Kistler™ Force plate (Model 9286AA, Kistler, Alton, UK), (W 400 X L 600 X H 35mm) with a sampling rate of 1000Hz. The planes of motion which postural sway was recorded in were the Az (sagittal), Ax (frontal), (see Figure 13). Range and standard deviation of the centre of pressure (CoP) excursions in the anterior-posterior (AP) and medio-lateral (ML) directions (AP range, AP SD, ML range, ML

SD respectively, all mm) and the CoP velocity (mm.sec^{-1}) (Hatton *et al.,* 2010, Raymakers *et al.,* 2005) were recorded during bipedal and unipedal quiet standing.
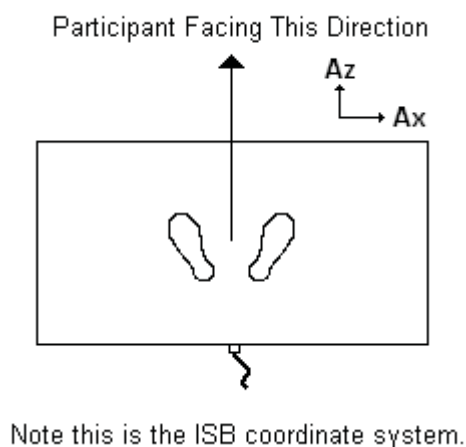
Figure 13: Example of force plate direction for AP (Az) and ML (Ax), (ISB stands for Institute of Biomechanics which the co-ordinate system is based upon).

To analyse muscle activation during standing balance a 16 channel Surface electromyography Bipoac (Model MP100, Goleta, CA, USA), was used to record Surface electromyography (SEMG) outputs using active surface electrodes (Type TSD150B, 11.4mm diameter) with a 20mm inter electrode distance (Hermens *et al.,* 2000). All SEMG recordings where sampled at a rate of 1000Hz (Merletti and Hermens, 2004; Hatton et al., 2010). EMG data was processed using AcqKnowledge software (Version 3.7.3, BIOPAC Systems, Inc.)[2].

To further investigate movements of body sections and investigate the use of the system; motion at the posterior aspect of the head and the fourth lumbar vertebrae (L4) were measured using the XBUS™ system (XSENS™ Technologies B.V., Enschede, Netherlands) simultaneously with the Kistler™ Force plate and EMG data capture. The XBUS™ system comprises a lightweight belt worn (400g) around the waist to which is attached an XBUS

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[2] Surface electromyography (SEMG) was collected as an additional measure outside the scope of the thesis, and is documented in the thesis to facilitate the reader for replications of data collection techniques, but no results are presented here. See appendix 9 for full instruction of set up for SEMG.

Master kit for data logging (XBUS Master, W100x L150 x H40 mm, 330g). In addition two MEMS lightweight inertial sensors were worn (W38 x L53 x H21 mm, 30g) which enabled multiple motion tracking (MTx) to occur.– One was attached to the participant's skin at the level of the Spinous Process of the forth Lumbar Vertebrae (L4) and the other to the posterior aspect of the head.

Deflections (degrees) in the coronal (roll), sagittal (pitch) and transverse (yaw) planes were recorded and the outcome measures used here were the maximum peak-to-peak range (degrees) in each plane during the balance trials (total movement).

Roll movements accounted for medial – lateral movement (x)

Pitch movements accounted for anterior – posterior movement (y).

Yaw movements accounted for a rotation movement (z).

4.7.4　**Head Orientation and Visual Target**

During postural sway measures participants were asked to look at a black circle approximately 10mm in diameter on a board positioned approximately 3m in front of the force plate (see Image **1**). The height of this black circle was adjusted to sit at eye level for each participant.

Image 1: Visual target placed in front of Kistler™ force plate.

4.7.5   **Exergaming Environment (IREX™)**

The Interactive Rehabilitation and Exercise system (IREX™) (GesturTek Health, Toronto, Canada) consists of; a camera, fabric green *screen* (W 3m X H 2.6m), data capture and processing box, widescreen Plasma screen (37, Hanaspree, Type T73B, Greyenstraat 65, Netherlands) and red gloves.

4.8   Procedure

On arrival for data collection at the Physiotherapy Research Laboratory at TU all participants were given a copy of the Participant Information Sheet (Appendix 4) and any questions they had were answered. They then signed the Informed Consent Form (Appendix 5). All effort was made by GB to arrange the time of data collection to suite the participants the best. The room temperature was at approximately 25 degrees Celsius (°C) during all data collection and all participants were required to report to the laboratory in gym based clothing, preferably shorts and tee-shirt and no raised heels. All participants were asked to report to the laboratory three times for 30 minutes each session over a two week period.

After documenting Informed Consent demographic data including weight (kg); height (cm); age (years); gender (M/F), dominant kicking leg and eye height were recorded for each participant (See Table 5.1.1). Eye height was collected in order to correctly position the visual target (black circle) during standing balance trials. Participants were asked to hold one end of a tape measure on the lateral side of their head at eye level and the distance above the floor was recorded.

Participants were then fitted with the XBUS™ system (XSENS™ Technologies B.V., Enschede, Netherlands). Two MEMS lightweight inertial sensors were worn – One was attached to the participant's skin at the level of the Spinous Process of the forth Lumbar Vertebrae (L4). L4 level was determined as the mid-line of the back at the Supra-Crystal Plane – determined by palpation of the lateral Iliac Crests (what people usually call the highest hip bones on either side of their body around or just above the level of their waist). This inertial sensor was attached to the Participant's skin using double sided hypo-allergenic adhesive tape. The other inertial sensor was worn at the posterior aspect of the head attached to an elasticised head-band placed around the head immediately above the ears (see Image **2**).
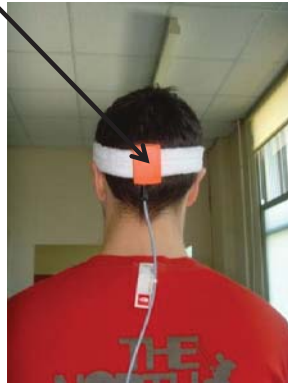
MEMS inertial sensor   XBUS™ master kit and belt

Image 2: XBUS™ inertial sensor and XBUS™ master kit as positioned during testing.

Once participants had been fitted with the XBUS™ system they were asked to: remove their shoes and stand barefoot on the Kistler™ force plate, look directly ahead at the visual target (black circle) positioned 3 m from the centre of the force plate at eye height (Lafond et al., 2004; Raymakers *et al.,* 2005; Brumels *et al.,* 2008; Pinsault and Vuillerme 2008; Santos et al., 2008; Hatton et al., 2011) and to stand as still as possible (Zok *et al.,* 2008).

Data collection began when participants had adopted a static standing position with arms by their sides and the pelvis in line vertically with the head.

Participants were initially asked to stand as still as possible for 30 seconds with both feet on the force plate (bipedal stance) - in their normal self-selected stance - for three trials. Between trials participants were asked to step of the force plate to allow calibration of the equipment - this formed a rest period of 30 seconds. The same procedure was followed for each of three trials.

After the third trial of bipedal standing a one minute rest break was given. Participants were then asked to repeat the procedure but standing on one leg, (their dominant - preferred kicking - leg) for 15 seconds (Clifford & Holder-Powell, 2010) of unipedal (one- legged standing). Between trials participants were asked to step of the force plate to allow calibration of the equipment - this formed a rest period of 30 seconds. The same procedure

was followed for a total of three trials. During unipedal standing trials GB stood behind the participant in order to assist should a participant lose their balance.

During all balance data collection trials (bi and uni pedal) participants kept their eyes open. The XBUS™ equipment was manually triggered to start collecting data at the same time as the force plate by GB. Following completion of the balance trials the Kistler™ force plate was wiped with a hard surface bactericidal sterilising wipe between participants. GB then removed the XBUS™ equipment and the corresponding area of skin wiped with an alcohol wipe and participants put their shoes back on.

Participants were then randomised by blind-card allocation (picking a sealed opaque envelope) to either the exergaming (IREX™), or mirror-matched gym based exercise group.

Prior to any exercise taking place GB showed all participants' examples of the exercises whether it was in the IREX™ environment or mirror matched exercise. Following the initial exercise demonstration all participants completed the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire for their specific exercise group. The questionnaire was completed prior to any exercise, but after the demonstration, to capture participant's initial views and thoughts about the exercise environment they had been allocated to.

Exercise Matching

In the mirror-matched exercise group participants were instructed by GB to perform balance based activities which matched the games played in the IREX™ group. The exercises were matched in terms of sequence, duration and mode of exercise by adopting open and closed chain limb movements of the same range and loading as was demanded in the games in the IREX™ group. GB instructed the participants in all of the exercises and the participants had to copy those movements (see Table **9** for example of movement patterns). The duration of the supervised sessions was the same as for the IREX™ group (30 minutes with 20 minutes of activity).

Prior to any testing pilot work was carried out by the researcher (GB) and a research colleague in order to match the movements of the games as best as possible. Movements were matched as best as possible in terms or sequence, and duration. As the use of mirror-matched exercise is a new concept, the nature of pilot work was essential in order to mimic the movements of the exergames as close as possible for both studies.

Table 9: Comparison of IREX™ exercise to mirror matched exercise session

Name	IREX™ Movement	Mirror Matched movements	Duration
Formula one	Steer a virtual car around a race track, moving body from side to side to avoid obstacles.	Start in a neutral standing position, move your torso from left to right and side lunge from alternative sides when instructed, by GB.	Full medial and lateral weight shifting
Snowboarding	Steer a snowboard down a track avoiding obstacles by stepping forward or backwards and jumping over barriers.	Start in a neutral standing position, lunge forward and backwards using alternative legs, when instructed by GB jump vertically, taking off and landing on two feet.	Anterior and posterior weight shifting of the centre of gravity over the base of support. Vertical jumping.
Sharkbait	Avoid getting eaten by sharks by moving body from side to side, squatting down and reaching out to the side and above head height for stars.	Start in a neutral standing position, alternate between squats, side lunges, front lunges and reaching and grasping motions to either side of the body and above head height.	Full medial and lateral weight shifting, side lunges and grasping movements (medial, lateral and vertically).
Soccer	Reaching up and forwards catch as many balls from entering the goal.	Lift both arms up and forwards and grasp your fingers and then drop them back down	Full medial and lateral weight shifting with Concentric shoulder flexion, finger flexion and hold and eccentric flexion back to neutral.

GB also actively took part in the sessions where necessary by giving directions of movement such as left and right and when to jump and squat in order to stimulate games such as Shark Bait.

Participants who were randomized into the IREX™ group were asked to wear their normal shoes; the only additional equipment required was a set of red gloves (provided with the IREX™ system) which are used to track participant's movements. Participants were asked to wash their hands before donning the gloves and the gloves were washed and dried between each data collection session.

Participants were asked to stand in front of a 10- foot wide green screen on an eight by ten florescent green non-slip foam mat which was positioned on a normal floor (see Image 3). The camera was calibrated prior to the exercise session beginning (see appendix 10).

The IREX™ system captures the video image of the person's image that is positioned in front of the green screen and the participant's image ("virtual self") is then superimposed into an interactive virtual world such as playing a goalkeeper in a soccer game. Real –time movements are performed when the participant interacts with the virtual environment, and tracked through the IREX™ software to produce positional data such as range of motion, and enable detection of accuracy of movements (i.e. saving goals in a soccer game).

Green backdrop

Video camera

Display Device

Computer and instillation

CD device

Floor mat
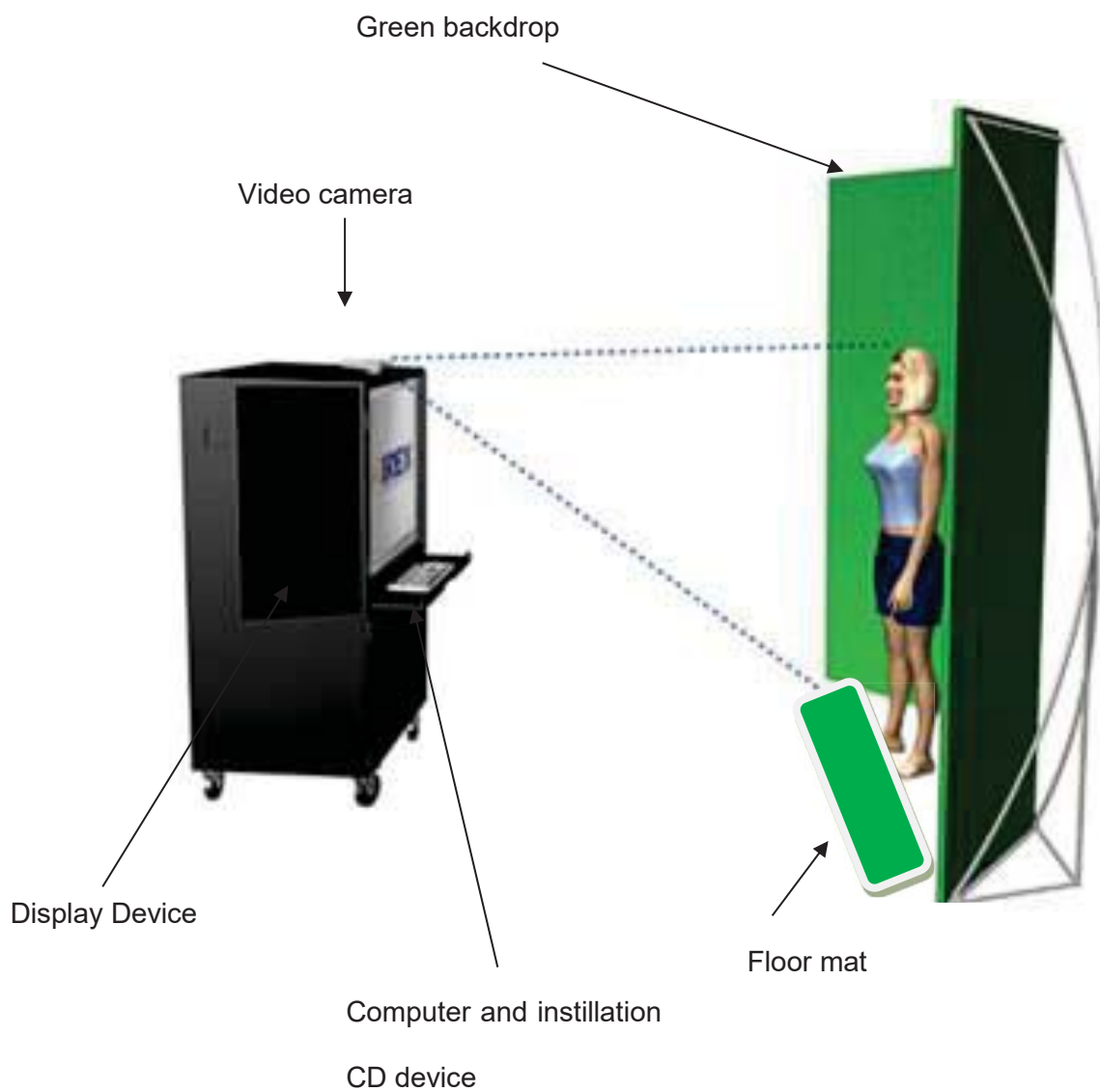
Image 3: Image of IREX™ system (IREX™ instruction Manual GesturTek Health) set-up

Once all of the camera calibration had been performed participants were asked to play four pre- selected balance based exergames, (Image 4 shows a participant playing a game).

Image 4: An example of a participant playing a game on the IREX™.

The four pre-selected balance based games required multi- directional movements of the feet, torso and upper body. The participant's own movements controlled the movement of their image within the game. The movements involved were trunk flexion, extension, side flexion, rotation and upper and lower limb movements. None of the movements needed to be fast or big – participants moved only as much, or as little as they wished to, and were always standing on level ground in all games, in their own shoes. Jumping was involved in some games, requiring double footed jumps, taking off and landing with two feet. The games were selected as the movements placed a demand on balance systems - e.g. such as reaching out to the sides, jumping on the spot and squatting - and could be replicated in the mirror-matched exercise group. There was no other equipment involved and no images were recorded.

Game one - Virtual Formula one racing - participants steered a car around a racing track by swaying from left to right (see Image 5). At the start of the game participants stood in a neutral standing position, with the aim of the game being to steer the car around a race track whilst avoiding obstacles on the track such as water melons. The participants were required to move their upper body in both medial and lateral directions depending on the track and step to the side on tighter corners.

Image 5: Example of Formula one racing game (IREX™)

Game two - Snowboarding – participants stood side-on and moved their image standing on a snowboard down a course (see Image 6). At the start of the game participants stood in a neutral standing position, side on to the camera. Using forward and backwards movements of their feet the participants controlled the direction of the board down the course making sure they avoided obstacles like tree stumps. To gain higher points participants jumped over ramps by performing a simple two footed jump on the stop taking off and landing with two feet.

Image 6: example of snowboarding game (IREX™).

Game three - Sharkbait – the participant's image was shown in virtual fish tank and they moved to avoid being eaten by sharks (see Image 7). The participants started in a neutral standing position front facing to the TV screen. The objective of the game is to catch as many stars as possible by using either their hands through reaching in both sagittal and coronal planes while simultaneously also avoiding the sharks. Avoiding the sharks required full body movements to either the left of right moving their feet or ducking down into a squat position.

Image 7: example of Sharkbait game (IREX™).

Game four - Soccer - the participant's image was shown as a goalkeeper in virtual goal and they moved their image to stop footballs entering the net (see Image 8). Participants started the game in a neutral standing position facing the TV screen and moved their arms straight up and to either the left or the right hand side to stop the balls hitting the net. Lower body movements required the participants to shift their weight from left to right to stop the ball with their feet.

Image 8: example of soccer game (IREX™).

At each exercise session, each game was played for 45 seconds, three times with a fifteen second recovery period between each game and a two minute rest period between each set of four games. Each session comprise, in total, playing the four games four times in the same order each time. The total time spent playing the games with rest periods included was

20 minutes, however allowing time to configure the initial settings participants were involved for approximately 30 minutes. All games were played at a low intensity setting (three on the 1-10 IREX™ game intensity scale).

At the end of the first exercise session participants in both groups were asked to complete the Flow State Scale questionnaire. GB then individually taught all participants in both groups a programme of home exercise. The home exercises included trunk flexion and extension and trunk rotation, shoulder abduction and adduction, lunges and side lunges (see appendix 11 for full details of home exercises). The aim of these was to perform whole body movements in a gentle and controlled manor in participant's own range of movements. Participants were instructed to carry out the exercises for 20 repetitions of each movement and keep repeating these movements at their own pace, until they had been exercising for ten minutes. Participants were asked to do these exercises every day when they did not attend for one of the three instructor based sessions in the laboratory for the two weeks following their first instructor based session.

The duration of the exergaming and mirror matched exercise was only 2 weeks in durations, as the subject population were non-active adults who predominately led a sedentary lifestyle. Therefore it was deemed necessary to have a short intervention to gain an understanding of whether exercise using and exergaming environment can be immersive and acceptable, without overloading participants to an exercise program over a longer period of time where they may not have adhered to the exercise sessions.

4.9 <u>Data reduction</u>

[3]Outcome measures of UTAUT, postural control using the Kistler™ force plate and XBUS™ system were measured in the first and last exercise session to compare both within-subjects factors (time with two levels – the start of the two week exercise programme (baseline) and the end of the programme (post-programme), and, between-subject factors (exercise (IREX™ versus mirror matched exercise).

The CoP AP and ML range and SD (mm) were calculated automatically using the force platform Bioware software package. CoP velocity was calculated using previous methods (Raymakers *et al.,* 2005) after low-pass filtering of the raw data at 10Hz. Mean CoP was calculated according to Raymakers formula for CoP, where Vd is displacement and n is number of samples.

CoP velocity (mm s-1): Σ Vd

$$n$$

The neck and pelvis roll, pitch and yaw data were calculated automatically using the XSENS SDK software package.

As participants performed three repetitions of quiet standing balance both for bipedal and unipedal stance at baseline and post exercise, an average value of the three trials was calculated for statistical analysis. Any value which appeared to be corrupt was further analysed, and deleted if necessary (see appendix 12 for normal and corrupt data file). A corrupt data file was identified by having all of the data points above the capturing threshold (i.e. when someone had contact with the force plate when calibration was occurring). At a minimum the average of 2 trials were analysed - participants for whom only one data point was obtainable were excluded from the analysis.

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[3] Only Flow state scale was taken post exercise after the first session.

4.10 <u>**Statistical Analysis**</u>

Data were analysed using Statistical Package for the Social Sciences Version 18 for Windows (SPSS, Chicago, IL, USA). Outcome measures were analysed as randomised following intention to treat principles; by separate analysis of covariance (ANCOVAs), comparing the post-test differences between the groups, with baseline values comprising the covariate with an alpha level set at 0.05. Within-subject differences of exercise over time for each measurement were investigated with a mixed analysis of variance (ANOVA). The tables of results will report means with standard deviations and 95% confidence intervals of the differences between exercise groups as well as the p-value.

Multiple regression analysis was performed for the UTAUT questionnaire, only, using behavioural intention as the dependant variable and performance expectance, effort expectancy, and social influences as the covariates in order to analyse if any of the covariates can significantly predict behavioural intention.

The aim of this investigation was to explore whether exercising in a virtual environment compared to standard exercise had any effect on technology acceptance and balance in a non-active healthy population. The statistical analysis as described above was believed to be the best method to achieve this as the ANCOVA allowed between group comparisons and the mixed ANOVA allowed the analysis of any differences over time to be analysed.

4.10.1 <u>**Reliability Testing**</u>

The thesis reports reliability between each psychological subscale for both the UTAUT and FSS using Cronbach's coefficient alpha (α). According to Nunnally & Bernstein (1994) 0.70 is an acceptable value to demonstrate reliability. Variables deemed unreliable will be excluded from any further analysis.

4.11 Results for a randomised controlled trial of non-active adults acceptance (behavioural intention) and flow experience (absorption in the activity) of exercising in: an exergaming environment (IREX™) or a mirror-matched exercise. Including an investigation of the XBUS™ system as a measure of postural control.

4.12 <u>Introduction</u>

This chapter will present the results obtained in study one when analysing postural sway and technology acceptance in a non-active population. This section will also present descriptive statistics such as mean, standard deviation, interclass correlations coefficients, 95% confidence intervals and effect size.

4.13 <u>Healthy non- active adults</u>

A convenience sample of 38 was initially recruited from a population of university staff and students who complied with the inclusion criteria. The CONSORT flow diagram (see Table 4.1 1) shows how many participants were recruited to the control and intervention group and reasons for any drop outs. Table 4.1 2 shows the descriptive characteristics of participants in study one. Because the equipment failed to capture the data sufficiently in 5 participants, data was analyzed from 33 participants (17 females) were analyzed with a mean (1SD) age 34.54 (11.97) years. Data from 17 participants were available for analysis in the exergaming group (age mean 31.0; 1SD 9.30; minimum-maximum 22-51; 7 men and 10 women). In the mirror-matched exercise there were 16 participants (age mean 37.5; 1SD 14.51; minimum-maximum 22-60; 7 men and 9 women).

CONSORT Flow Diagram

Enrolment

Assessed for eligibility (n=38)

Excluded (n=0)

Randomized (n=38)

Allocation

Allocated to intervention (n=19)

Received allocation intervention (n=19)

Allocated to intervention (n=19)

Received allocation intervention (n=19)

Enrolment

Lost to follow-up (n=0)

Lost to follow-up (n=0)

Analysis

Analysis (n=17)

- Excluded from analysis (error in data capture) (n=2)

Analysis (n=16)

- Excluded from analysis (error in data capture) (n=3)

Table 4.1 1 CONSORT flow diagram for healthy non-active recruitment and exclusion

Table 4.1 2: Demographic data for healthy non- active subject population

Gender	Age (years)	Height (cm)	Weight (kg)	Dominant kicking leg
	Mean (SD)	Mean (SD)	Mean (SD)	
21 (M) 17 (F)	34.54 (11.97)	172 (12.5)	75 (15)	33 (R) 5 (L)

4.14 Psychological Analysis of Exergaming verse mirror matched gym based exercise with no virtual stimuli

4.14.1 Reliability for Unified Theory of Technology Acceptance (UTAUT)

Table 4.1 3 shows the reliability analysis performed on UTAUT subscales at pre and post exercise testing to assess internal reliability within the subscales.

Reliability analysis was performed for each subscale for UTAUT questionnaire using Cronbach's coefficient alpha as a measure of internal consistency within variables. Alpha levels of 0.70 or above are deemed as an acceptable value to demonstrate reliability (Nunnally & Bernstein 1994). This was performed prior to any statistical analysis for both pre and post exercise testing. All of the variables showed good reliability apart from social influences (SI); therefore this was excluded from the statistical analysis of the questionnaire due to its poor internal reliability. Cronbachs alpha scores ranged from 0.80 to 0.96 at before exercise (excluding SI) and 0.72 to 0.92 after exercise, showing good internal consistency for each subscale in the UTAUT model.

Table 4.1 3 Cronbach's Alpha Scores for Subscales for UTAUT

Subscale	Before exercise Cronbach's alpha	Post-exercise Cronbach's alpha
PE	0.85	0.80
EE	0.84	0.88
SI	**0.42***	**0.39***
FC	0.80	0.72
BI	0.96	0.92

Note * is unreliable data as (α) < 0.70

4.14.2 Reliability for Flow State Scale (FSS)

The same reliability analysis was applied to FSS. The results showed that all 9 subscales where reliable at before exercise assessment, but post exercise testing clear goals (CG), unambiguous feedback (UF) and loss of self-consciousness (LS), failed to reach reliability at set at 0.70, however these variables remained in the analysis due to earlier high baseline scores (see Table 4.1 4). Alpha internal consistency estimates for all for all of the subscales ranged from 0.71 to 0.85 for baseline assessment and 0.61 to 0.86 for post exercise analysis.

Table 4.1 4 Reliability analysis for Flow State Scale

Subscale	Before exercise Cronbach's alpha	Post-exercise Cronbach's alpha
AE	0.75	0.86
CG	0.81	0.68
CB	0.74	0.70
CT	0.85	0.82
PC	0.75	0.70
UF	0.74	0.61
AM	0.71	0.81
TT	0.84	0.71
LS	0.73	0.61

4.15 Effects of independent variables on technology acceptance

Levels of technology acceptance were high overall, with performance expectancy higher in the IREX™ group (see Table 4.1 5). Analysis of covariance (ANCOVA) results, with before exercise values as the covariate confirmed this result as statistically significant for performance expectancy, $F (1, 35) = 5.34$, $p = 0.03$, $\varepsilon^2 = 0.14$, reflecting a higher level of PE in the exergaming (IREX™) group after completion of the exercise programme. There were no significant differences between groups on the other UTAUT subscales.

A Mixed analysis of variance (ANOVA) demonstrated that the main effects of time and intervention were not statistically significant. The main effect of the intervention (exercise) and the interaction effect of the intervention with time was only significant for PE $F (1, 35) = 4.96$, $p = 0.03$, $\varepsilon^2 = 0.12$, (see Table 4.1 6). The interaction effect showed that the mean scores ± 1SD improved for the IREX™ group over time, 4.51 (1.33) pre exercise to 5.24 (1.32) post exercise, whereas the mirror-matched exercise had reduced scores over time 4.74 (0.98) to 4.50 (0.78) respectively. No other interaction effects were found for the remaining UTAUT variables.

Table 4.1 5 *Descriptive statistics (Mean ± SD) for technology acceptance variables*

	Before exercise		Post-exercise	
	IREX™	[4]Mirror-Matched	IREX™	Mirror-Matched
Variable	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Performance Expectancy (PE)	4.51 (1.33)	4.84 (0.82)	5.24 (1.32)	4.66 (0.61)
Effort Expectancy (EE)	5.99 (1.00)	5.64 (1.05)	6.20 (1.11)	5.55 (1.14)
Facilitating Conditions (FC)	5.41 (1.32)	5.89 (0.76)	4.93 (1.41)	5.46 (1.27)
Behavioural Intention (BI)	4.11 (2.15)	4.13 (1.32)	4.67 (2.22)	4.15 (1.36)

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[4] Note mirror-matched stands for mirror- matched exercise.

Table 4.1 6 Within group changes over time mean difference (95% CI) and differences between group (ANCOVA) for UTAUT.

	Within-group change over time (Mixed ANOVA)		ANCOVA Adjusted post-intervention difference between groups
	IREX™	Mirror-Matched	IREX™- Mirror-Matched
	Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Performance Expectancy (PE)	-0.72 (-1.41 to -0.03) *	0.13 (-0.28 to 0.55)	0.73 (0.07 to 1.38) *
Effort Expectancy (EE)	-0.21 (-0.81 to 0.39)	0.04 (-0.63 to 0.71)	0.52 (-0.02 to 1.24)
Facilitating Conditions (FC)	-0.50 (-0.22 to 1.21)	0.39 (-0.28 to 1.06)	0.44 (-1.32 to 0.43)
Behavioural Intention (BI)	0.04 (-0.69 to 0.76)	-0.62 (-0.65 to 0.61)	0.06 (-0.94 to 0.82)

* Significant at the $p < 0.05$ level; **Significant at the $p < 0.01$ level.

4.15.1 Regression analysis of the UTUAT

Multiple regression results are presented in Table 4.1 7.

Firstly only direct effects were regressed (PE, EE, FC, age, intervention and gender) against BI and were statistically significant both before exercise $F_{(7, 30)} = 2.43$, $p = 0.04$, $R^2 = 0.21$ and after exercise $F_{(7, 30)} = 9.94$, $p < 0.01$, $R^2 = 0.63$. Pre-exercise R^2 indicates that 21% of behavioural intention can be explained by the independent variables (PE, EE, FC, age, intervention and gender). However, post-exercise behavioural intention can be explained by 63% of the time by the independent variables (PE, EE, FC, age, intervention and gender).

When the independent variables were analysed separately only performance expectancy significantly predicted behavioural intention before exercise ($t_{(37)} = 3.70$, $p < 0.001$ and after exercise PE ($t_{(37)} = 6.36$, $p < 0.01$, FC ($t_{(37)} = 3.57$, $p = p < 0.01$, and gender ($t_{(37)} = 2.24$, $p = 0.03$ were all, separately, significant predictors of behavioural intention (see Table 4.1 7).

When interaction terms were included in the model, adjusted R^2 values increased before exercise (0.21) and after exercise (0.51). Before exercise R^2 change was 0.44, indicating a 44% of extra value explained by adding the interaction effect; however, this increase was not significant ($p=0.06$). After exercise the results were similar, with adjusted R^2 values increasing from 0.63 to 0.66 and an R^2 change of 0.16 (16%) which was not significant. The main effect of the intervention (exercise) did not have any statistical significance when added to the model at either pre of post exercise, nor did age have any significant effect on predicting behavioural intention. Overall performance expectancy was the strongest predictor of behavioural intention.

Table 4.1 7 Multiple Regression Analysis for technology acceptance variables

	Before Exercise		After Exercise	
	D Only	D +1	D Only	D +1
	β	β	β	β
R^2	*0.36	0.80	***0.70	0.86
Adjusted R^2	0.21	0.51	0.63	0.66
R^2 Change		0.44		0.16
Performance Expectancy (PE)	**0.70	0.60	***0.71	-0.81
Effort Expectancy (EE)	-0.06	-0.20	-0.07	0.17
Facilitating Conditions (FC)	0.01	3.21	**0.41	-0.46
Age (AGE)	-0.26	-0.26	0.18	-0.24
Gender (GDR)	-0.05	-0.95	*0.23	0.35
Intervention (Int)	-0.10	-0.78	0.16	-0.03
PE X GDR		0.24		0.21
EE X GDR		0.69		0.80
FC X GDR		-2.50		-0.02
PE X AGE		-0.06		1.02
EE X AGE		-0.51		-1.34
FC X AGE		-1.07		0.46
PE X Int		0.15		0.27
EE X Int		-0.34		0.01
FC X Int		0.18		0.33
AGE X GDR		-0.01		-0.16
AGE X Int		0.34		-0.29
GENDER X Int		1.29		-0.08

Note D Only: Direct effects only; D +1: Direct effects and interaction terms. Greyed out cells are not applicable for specific column.

*p<0.05 **p<0.01 ***p<0.001.

4.16 **Effects of independent variables of flow experience**

4.16.1 **Effects of independent variables on flow experience between exercise groups.**

Overall, levels of flow experience were high and even higher at the end of the intervention (see Table 4.1 8). ANCOVA showed no significant differences on any of the measures at the end of the intervention, nor were any 95% CI none close to zero for either lower of upper limit.

Mixed ANOVA confirmed the increase in flow showing significant post-test differences for Autotelic Experience $F (1, 35) = 6.95$, $p = 0.01$, $\varepsilon2 = 0.16$ clear goals, $F (1, 35) = 4.61$, $p = 0.04$, $\varepsilon2 = 0.11$ and for transformation of time $F (1, 35) = 10.88$, $p = 0.002$, $\varepsilon2 = 0.23$. Although both groups showed improvement over time for AE, CG, and TT the 95% CI showed that the upper limits were closer to zero indicating greater levels of significance in favour of the mirror-matched exercise. There were no significant within-subject changes for the remaining Flow variables for time alone. The main effect of the intervention (exercise) and the interaction effect of the intervention with time was only significant for paradox of control $F (1, 35) = 4.97$, $p = 0.03$, with mean scores ± 1SD lower in the IREX™ group over time 4.20 (0.71) pre exercise to 4.05 (0.77) post exercise, whereas the mirror-matched exercise improved over time 3.71 (0.55) to 4.06 (0.48) respectively, (see Table 4.1 9).

Table 4.1 8 *Descriptive Statistics (Mean ± SD) for flow experience subscales*

Variable	Before exercise IREX™ Mean (SD)	Before exercise Mirror-Matched Mean (SD)	Post-exercise IREX™ Mean (SD)	Post-exercise Mirror-Matched Mean (SD)
Autotelic Experience	3.96 (0.70)	3.50 (0.61)	4.09 (0.75)	3.85 (0.48)
Clear Goals	4.17 (0.90)	3.51 (0.52)	4.33 (0.61)	4.20 (0.45)
Challenge- Skill Balance	4.05 (0.74)	3.78 (0.60)	4.03 (0.75)	4.02 (0.59)
Concentration of Task	4.43 (0.64)	3.70 (0.76)	4.17 (0.95)	3.84 (0.61)
Paradox of Control	4.20 (0.71)	3.64 (0.57)	4.05 (0.77)	4.03 (0.46)
Unambiguous Feedback	4.00 (0.69)	3.72 (0.53)	4.12 (0.66)	4.41 (0.21)
Action- Awareness Merging	3.53 (0.87)	3.56 (0.49)	3.59 (1.00)	3.78 (0.66)
Transformation of Time	3.22 (1.16)	3.06 (0.60)	3.67 (0.86)	3.39 (0.69)
Loss of Self- Consciousness	4.47 (0.62)	3.84 (0.56)	4.46 (0.59)	4.03 (0.36)

Table 4.1 9: Within group changes over time mean difference (95% CI) and differences between group (ANCOVA) for flow state scale.

	Within-group change over time (Mixed ANOVA)		ANCOVA Adjusted post-intervention difference between groups
	IREX™	Mirror-Matched	IREX™- Mirror-Matched
	Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Autotelic Experience	-0.13 (-0.48 to 0.22)	-0.41 (-0.66 to -0.16)*	0.02 (-0.40 to 0.35)
Clear Goals	-0.16 (-0.57 to 0.26)	-0.34 (-0.60 to -0.09)*	0.00 (-0.32 to 0.31)
Challenge- Skill Balance	0.03 (-0.38 to 0.43)	-0.22 (-0.47 to 0.03)	0.14 (-0.54 to 0.30)
Concentration of Task	0.26 (-0-.23 to 0.76)	-0.05 (-0.38 to 0.28)	0.08 (-0.46 to 0.61)
Paradox of Control	0.14 (-0.24 to 0.53)	-0.36 (-0.63 to -0.08)*	0.22 (-0.64 to 0.20)
Unambiguous Feedback	-0.12 (-0.37 to 0.13)	-0.63 (01.62 to 0.36)	0.33 (-1.13 to 0.65)
Action- Awareness Merging	-0.07 (-0.56 to 0.43)	-0.22 (-0.63 to 0.18)	0.22 (-0.77 to 0.32)
Transformation of Time	-0.45 (-0.92 to 0.03)	-0.42 (-0.71 to -0.14)*	0.14 (-0.29 to 0.57)
Loss of Self- Consciousness	0.01 (-0.33 to 0.36)	-0.13 (-0.39 to 0.12)	0.24 (-0.12 to 0.60)

* Significant at the $p < 0.05$ level; **Significant at the $p < 0.01$ level.

4.17 **Postural Sway during Quiet Standing in Healthy Young Non- Active Adults**

4.17.1 **Postural sway results between exercise groups**

Table 4.1 10 shows the baseline mean and SD scores for each of the balance during both bipedal and unipedal standing for the exergaming and mirror matched gym based exercise with no virtual stimuli. Pre- exercise mean scores for parameters of postural control (AP SD, AP range, ML SD, ML range and CoP velocity) for unipedal standing were lower in the mirror matched gym based exercise with no virtual stimuli group compared to the exergaming group. Similar results occurred in bipedal standing in that the mirror matched gym based exercise with no virtual stimuli had lower mean scores apart from in AP range.

Table 4.1 11 shows the results following an ANCOVA to analyses the between group differences with baseline measures acting as the covariates and the within- subjects effects over time (mixed ANOVA) during bipedal and unipedal quite standing. There was no significant differences between exercise groups for any postural sway measures (AP SD, AP range, ML SD, ML range and CoP velocity) for bipedal standing, nor were any notable trends observed. In unipedal balance, AP (SD) $F_{(1, 33)} = 12.75$, $p = 0.001$, $\varepsilon2 = 0.29$ and AP range $F_{(1, 33)} = 4.74$, $p = 0.04$, $\varepsilon2 = 0.13$ were statistically significantly lower after the two week programme in the exergaming group (IREX™) compared to the mirror-matched exercise. There was no statistically significant difference between the exercise groups for unipedal CoP velocity, but zero difference was close to the lower limit of the 95% confidence interval indicating a trend in favour of the exergaming group.

There was no statistically significant difference between the exercise groups for unipedal ML sway, nor were any notable trends observed.

Within- group change over time (mixed ANOVA) showed that for bipedal stance there was a statistically significant difference occurring over time from baseline to post exercise testing for ML SD $F_{(1, 33)} = 5.08$, p =0.03, $\varepsilon2 = 0.14$ showing that both the exergaming group and mirror-matched exercise showed an reduction in postural sway in the ML direction. No other sway variable reported any statistical differences over time.

For unipedal stance the exergaming (IREX™) group improved on all 5 balance variables (AP SD, AP range, ML SD, ML range and CoP Velcotiy). Only AP SD showed any significance occurring over time with a significant time * exercise interaction effect occurring in unipedal stance $F_{(1, 33)} = 5.18$, p = 0.03 $\varepsilon2 = 0.14$. This was in favor of the IREX™ as the mean average ± 1SD for AP SD reduced from pre exercise 8.15 (3.37)mm to 6.70 (1.28)mm, whereas in the mirror-matched exercise AP SD increased from pre to post exercise, 8.00 (2.69)mm to 8.41 (2.30)mm.

Table 4.1 10: Descriptive mean ± SD for postural control during bipedal and unipedal stance.

		Pre-Programme		Post-Programme	
		IREX™	Mirror-Matched	IREX™	Mirror-Matched
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Bipedal	**AP SD**	4.28 (1.88)	4.20 (1.10)	4.51 (2.13)	4.67 (1.70)
	AP Range	20.75 (8.72)	21.35 (4.91)	23.00 (11.01)	23.52 (18.66)
	ML SD	2.18 (1.11)	1.80 (0.66)	2.60 (1.31)	2.16 (1.06)
	ML Range	13.63 (7.64)	10.46 (3.47)	15.17 (7.84)	14.04 (10.93)
	COP Velocity	23.18 (6.22)	19.33 (4.34)	23.08 (7.22)	18.66 (2.72)
Unipedal	**AP SD**	8.15 (3.37)	8.00 (2.69)	6.70 (1.30)	8.41 (2.30)
	AP Range	42.00 (23.14)	40.85 (14.55)	33.89 (7.09)	41.92 (15.27)
	ML SD	9.17 (6.65)	7.53 (6.21)	5.87 (2.51)	7.63 (4.83)
	ML Range	46.22 (34.85)	34.45 (23.22)	32.04 (15.36)	38.78 (23.74)
	COP Velocity	51.19 (14.46)	50.86 (17.68)	43.33 (9.67)	49.51 (12.81)

Table 4.1 11 Within group changes over time mean difference (95% CI) and differences between group (ANCOVA) for postural control during bipedal and unipedal standing.

		Within-group change over time (Mixed ANOVA)		ANCOVA Adjusted post-intervention difference between groups
		IREX™	**Mirror-Matched**	**IREX™- Mirror-Matched**
		Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Bipedal	**AP SD**	-0.23 (-1.07 to 0.61)	-0.47 (-1.41 to 0.47)	-0.21 (-1.39 to 0.96)
	AP Range	-2.25 (-6.76 to 2.25)	-2.17 (05.78 to 1.44)	-0.01 (-5.65 to 5.65)
	ML SD	-0.42 (-1.05 to 2.18)	-0.36 (-0.71 to -0.02)*	0.15 (-0.57 to 0.87)
	ML Range	-1.54 (-4.78 to 1.69)	-3.58 (-8.05 to 0.88)	-2.00 (-7.52 to 3.52)
	COP Velocity	0.09 (-3.12 to 3.31)	0.66 (-1.43 to 2.76)	2.31 (-1.29 to 5.90)
Unipedal	**AP SD**	1.45 (-1.23 to 0.41)*	-0.41 (-1.23 to 0.41)	-.76 (-2.77 to -0.76)**
	AP Range	8.12 (-3.08 to 6.24)	-1.07 (-8.38 to 6.24)	-8.28 (-16.03 to -0.52)*
	ML SD	3.31 (0.29 to 6.32)	-1.00 (-4.51 to 4.31)	-1.84 (-4.59 to 0.87)
	ML Range	14.58 (-4.25 to 33.41)	-4.33 (-22.91 to 14.26)	-6.44 (-20.79 to 7.90)
	COP Velocity	7.87 (0.28 to 15.46)	1.35 (-6.13 to 8.82)	-6.29 (-13.20 to 0.62)

* Significant at the $p < 0.05$ level; ******Significant at the $p < 0.01$ level

4.18 XBUS Pelvic and Neck Deflections Results.

4.18.1 Differences between exercise groups in neck and pelvic tilt during Bipedal and Unipedal Standing.

Table 4.1 12 shows the descriptive statistics of baseline and post-test mean and SD results for both exercise groups. There appeared to be no trend occurring from pre to post exercise in Bipedal neck roll, pitch or yaw, however for pelvic roll, pitch and yaw both exercise groups showed a decrease in the amount of movement occurring. During unipedal analysing both exercise groups showed a decrease in neck roll, pitch and yaw over time and the IREX™ group increased the amount of movement in pelvic roll and pitch where the mirror-matched exercise reduced the amount of movement and during pelvic yaw both groups decreased the amount of movement over time.

Table 4.1 13 shows the ANCOVA results for between groups differences and mixed ANOVA results for within group differences occurring over time (pre to post exercise). During bipedal standing the ANCOVA results showed no statistical differences between exercise groups, nor did they indicate and noticeable trends occurring. However, during unipedal standing pelvic pitch (AP movement) was statistically significant $F (1, 26) = 5.98$ $p = 0.02$, $\varepsilon 2 = 0.21$ with higher values in the exergaming group. No other significance was established for between group differences, nor were any 95%CI indicating any potential significance occurring.

In bipedal standing neck roll (rotation) and yaw (ML) improved more in the IREX™ exercise group compared to the mirror-matched exercise, whereas in bipedal pitch (AP) the mirror-matched exercise improved by more. In unipedal neck roll, pitch and yaw there were reductions in movement in both the mirror-matched exercise and the IREX™ exercise group.

During pelvic movement for bipedal stance the IREX™ group improved more than the standard in pelvic roll, whereas during pelvic pitch and yaw the mirror-matched exercise had a greater decrease in movement. For unipedal analysis only the mirror-matched exercise

group had a greater level of decrease in pelvic roll and yaw compared the IREX™ group and the mirror-matched exercise group had a decrease from pre to post testing in pelvic tilt, with the IREX™ group increasing in the amount of pelvic tilt (AP) post exercise.

For bipedal stance significant post-test differences were established for pelvic roll only, $F_{(1, 26)} = 4.21$, $p = 0.05$, $\varepsilon 2 = 0.15$. Both exercise groups decreased the amount of pelvic roll over time with the IREX™ group showing a greater level of decrease (0.85°) compared to the mirror-matched exercise group (0.65°)

For unipedal stance neck roll (rotation) and neck yaw (ML) significantly improved over time, $F_{(1, 26)} = 5.59$, $p = 0.03$, $\varepsilon 2 = 0.19$ and $F_{(1, 26)} = 8.97$, $p = 0.01$,, $\varepsilon 2 = 0.27$ respectively. For neck roll both groups decreased over time in the amount of movement with a greater decrease in the mirror-matched exercise group (1.45°) compared to the IREX (0.78°). Likewise for neck yaw the same pattern occurred with the mirror-matched exercise group having a greater decrease (1.86°) compared to the IREX group (1.13°).

Table 4.1 12: Mean scores ± SD for *Neck and pelvic deflection during unipedal and bipedal quiet standing.*

		Pre-Programme		Post-Programme	
		IREX™	**Mirror-Matched**	**IREX™**	**Mirror-Matched**
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Bipedal	**Neck Roll (Deg)**	3.88 (1.28)	3.59 (2.06)	3.40 (2.69)	3.66 (3.06)
	Neck Pitch (Deg)	2.94 (1.70)	2.97 (1.32)	2.99 (1.01)	2.73 (1.16)
	Neck Yaw (Deg)	4.51 (1.30)	4.67 (2.36)	4.44 (2.10)	4.91 (3.16)
	Pelvic Roll (Deg)	3.09 (2.57)	2.78 (1.72)	2.24 (1.31)	2.10 (0.85)
	Pelvic Pitch (Deg)	2.68 (2.13)	1.98 (0.68)	1.84 (0.78)	1.80 (0.75)
	Pelvic Yaw (Deg)	3.91 (3.14)	3.56 (2.36)	3.56 (1.91)	2.99 (2.09)
Unipedal	**Neck Roll (Deg)**	5.71 (2.23)	5.76 (2.17)	4.93 (1.03)	4.31 (1.93)
	Neck Pitch (Deg)	4.32 (2.07)	4.09 (1.55)	3.55 (1.89)	3.52 (1.09)
	Neck Yaw (Deg)	6.49 (2.78)	6.51 (2.40)	5.36 (1.80)	4.65 (1.69)
	Pelvic Roll (Deg)	4.96 (1.25)	5.43 (2.77)	5.00 (2.71)	4.38 (2.44)
	Pelvic Pitch (Deg)	2.53 (1.29)	2.52 (1.22)	3.09 (1.63)	1.86 (0.63)
	Pelvic Yaw (Deg)	6.83 (2.66)	6.39 (2.46)	5.78 (2.44)	5.10 (2.61)

Table 4.1 13: Within group changes over time mean difference (95% CI) and differences between group (ANCOVA) for XBUS™ data for Neck and Pelvic deflections during standing balance.

		Within-group change over time (Mixed ANOVA)		ANCOVA Adjusted post-intervention difference between groups
		IREX™	Mirror-Matched	IREX™- Mirror-Matched
		Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Bipedal	Neck Roll (Deg)	0.48 (-1.26 to 2.22)	0.07 (-2.45 to 2.31)	-0.24 (-2.64 to 2.15)
	Neck Pitch (Deg)	0.05 (-1.19 to 1.09)	0.24 (-0.87 to 1.35)	0.26 (-0.64 to 1.16)
	Neck Yaw (Deg)	0.10 (-1.49 to 1.68)	0.24 (-3.11 to 2.62)	-0.53 (-2.62 to 1.56)
	Pelvic Roll (Deg)	0.86 (-0.38 to 2.09)	0.67 (-0.32 to 1.67)*	0.05 (-0.75 to 0.85)
	Pelvic Pitch (Deg)	0.84 (-0.31 to 1.99)	0.18 (-0.57 to 0.94)	-0.02 (-0.66 to 0.62)
	Pelvic Yaw (Deg)	0.36 (-0.83 to 1.54)	0.57 (-1.32 to 2.47)	0.45 (-1.00 to 1.89)
Unipedal	Neck Roll (Deg)	0.78 (-0.49 to 2.06)	1.45 (-0.21 to 3.12)*	0.62 (-0.60 to 1.86)
	Neck Pitch (Deg)	0.77 (-0.90 to 2.44)	0.57 (-0.74 to 1.88)	0.05 (-1.26 to 1.35)
	Neck Yaw (Deg)	1.13 (-0.37 to 2.62)	1.86 (0.29 to 3.43)**	0.71 (-0.39 to 1.80)
	Pelvic Roll (Deg)	-0.04 (-1.63 to 1.55)	1.05 (-1.30 to 3.39)	0.66 (-1.50 to 2.82)
	Pelvic Pitch (Deg)	-0.55 (-1.92 to 0.81)	0.62 (-0.20 to 1.50)	1.23 (0.19 to 2.27)*
	Pelvic Yaw (Deg)	1.05 (-0.84 to 2.95)	1.27 (-1.45 to 3.99)	0.73 (-1.36 to 2.82)

* Significant at the $p < 0.05$ level; **Significant at the $p < 0.01$ level

4.19 <u>Relationship between Balance and XBUS data.</u>

As the results show, during unipedal stances there is a statistically significant difference occurring between groups for AP SD and AP range in favour of the IREX™ group, showing a reduced amount of sway occurring post-test. Interestingly, the results from the XBUS™ data show the opposite effect occurring at the pelvic region in that pelvic pitch (AP) is reduced in the mirror matched exercise.

Therefore it was necessary to perform a regression model to analyse any relationship occurring between the two variables.

The results showed that pelvic pitch was negatively correlated with unipedal AP SD, r = -0.20 and AP range, r = -0.23, both results showed no statistical significance occurring p > 0.05.

4.20 Summary

The results would suggest that exergaming produced high levels of intention to use the exercise system again. There were significant between group differences occurring for performance expectancy in favour of the exergaming group and performance expectancy was a significant predictor of behavioural intention following regression analysis. This result tentatively suggests that exergaming can be an acceptable method of exercise and people are inclined to use exergaming in the future (intention). The immersion into the activity was also evident through the flow states scale, despite no statistical differences occurring between exercise groups, it did emerge that over time there was some potential levels of immersion into the exercise. Both the UTAUT and FSS offer a novel insight and robust approach to analysing the potential use of exergaming as a method of exercise for non-active healthy adults.

In relation to the secondary aim, the results showed the potential of balance based training using an exergaming technique. Balance data showed that during unipedal stance the IREX™ group has significantly improved in both AP SD and AP range compared to the mirror-matched exercise. All of the unipedal balance sway measures (AP SD, AP range, ML SD, ML range and CoP velocity) improved from pre to post exercise for the IREX™ group during, however this was not at a statistically significant level. Only an interaction effect of time x intervention was found to be significant for APSD in favour of the IREX™ group, in that postural sway reduced over time for the IREX™ group, but increase over time for the mirror-matched exercise. The results with the XBUS™ data offer some new insight into the function that the upper body plays in relation to quite standing balance. As essentially, it appears that movements at the pelvic region may have occurred which minimized the overall excursion of the entire system's centre of gravity. This allowed greater overall body equilibrium in the sagittal plane, in other words smaller excursions of the whole systems centre of gravity were detected at ground level.

This chapter shows the potential use of exergaming to improve exercise behavioural intention to use the exergaming system over mirror-matched exercise and also for the potential use in balance training in a group of non-active healthy adults.

4.21 Discussion for a randomised controlled trial of non-active adults acceptance (behavioural intention) and flow experience (absorption in the activity) of exercising in: an exergaming environment (IREX™) or a mirror-matched exercise. Including an investigation of the XBUS™ system as a measure of postural control.

4.22 <u>Introduction</u>

This chapter will discuss the experimental results from study one, whilst referring to previous literature surrounding the topic of exergaming and its application technology acceptance and immersion into the exercise and also the effects of exergaming on balance functioning.

4.23 <u>Unified Theory of Technology Acceptance and Use of Technology (UTAUT) and Flow State Scale (FSS).</u>

The current study is the first in exergaming literature to explore the use of UTAUT as a psychometric measure of technology acceptance and behavioural intention. Previously UTAUT research has been predominately administrated in the information technology and computing world with evidence to support the use of UTAUT (Shun Wang and Wei Shih 2009). For the psychological results obtained during the investigation it was evident that performance expectancy (PE) was significantly higher in the exergaming-exercise group after completion of the course of exercise than in the mirror-matched exercise group (p<0.05). Therefore, the primary H_1 alternative hypothesis was accepted as compared to mirror matched exercise, there was a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention). Participants found exergaming exercise a more useful way to perform exercise. There was no significant difference between the groups on other technology-acceptance variables. There was no significant difference in age for the two exercise groups; in addition, multiple regression analysis showed that neither age nor the exercise intervention had an effect on behavioural intention. More so multiple regression analysis showed that performance expectancy was also a significant predictor of behavioural intention after exercise for both groups (p<0.05). The results would also suggest

the usefulness of using the technology acceptance model for exergaming research and offers a new insight into psychological perceptions and beliefs towards exergaming. Although the results showed meaningful data, it should be noted, that more robust and longitudinal work needs to be established concerning the technology acceptance model and its use in the exergaming filed before any true generalisations can be generated.

A possible reason as to why PE was significant in the exergaming may be due to exergaming being perceived as more enjoyable and a fun activity to do as opposed to mirror matched exercise, which may encourage people who are normally sedentary to exercise (Pascha et al., 2009). Thornton et al (2005) concurs, when comparing the effects of exergaming (virtual reality) compared to conventional exercise in a group of adults with Traumatic Brain Injury, they found that people in the exergaming group perceived the exercise as "novel, fun and interesting" way to exercise (Thornton et al., 2005). In turn, this could have had an influence of people's performance expectancy and ultimately their behavioural intention to use the exergaming system for exercise, as they may associate exergaming as more enjoyment and play like activity rather than mirror matched gym based exercise with no virtual stimuli and use the exergaming system as a way to motivate them to exercise and ultimately to help them maintain exercise. In relation to the effect of enjoyment having on performance expectancy and, ultimately, behaviour intention to use, Sun and Zhang (2008) analysed perceived enjoyment as an aspect or technology acceptance on a group of general internet users. The results showed that perceived enjoyment can have a direct impact on perceived usefulness (PE in our current study). Therefore, a potential reason as to why PE was significantly higher in the exergaming group than the mirror matched exercise could be that exergaming is more enjoyable. The results indicate the potential for the use of exergaming compared to mirror matched exercise on a non-active healthy adult population, with levels of acceptance of exercise and flow experience as high as or higher than those achieved with mirror-matched exercise. In addition, both performance expectancy and (after completion of the exercise programme) were predictors

of intention to exercise.   Therefore, efforts to promote exercise of both types should emphasize its usefulness and address conditions that could facilitate exercise.

A possible explanation for PE being a significant predictor of BI both at the baseline and at the end of the exercise program is that the participants at baseline had already seen the system in action before conducting any exercise and could see the potential use of the system for exercise. In contrast, the participants would only be able to gain and rate the system in terms of EE and FC after actual experience. A possible explanation why EE was not significant could the easy nature of the exercise throughout the testing, as intensity remained the same over the two week duration. In support, Davis and Venkatesh (2004) assessed perceived usefulness (PE in the current study), perceived ease of use (PEOU/ EE) and intention to use the system (BI) in a study analysing people's initial thoughts (baseline), following a month's training (post) and 3 months follow-up when in a group of customer service representatives using a new IT product. The results suggest and support the current findings that PE can form initial views at baseline without any physical experience of the equipment, whereas EE and FC require hands-on interaction with the system in order for people to develop thoughts regarding the new system and its ease of use.

The results from the Flow State Scale showed that there were no statistically significant differences occurring between groups for any of the nine sub-scales for flow state which partly agreed with H_3 null hypothesis that there would be no difference between the exercise groups over time. However, within-subject increases over time were significant for autotelic experience, clear goals, and transformation of time from baseline to post exercise programme, thus supporting the H_4 alternative hypothesis. Despite the short intervention, improvements over time could be due to participants become more experienced with the exercises and as a result goals could be perceived as easier to attain and more in balance with their skill level. Limited research has been conducted in respect to flow and exergaming (see chapter 2 for more detail). Table 4.1 14 shows the current thesis method of measuring

flow and the significance over time compared to current literature that has applied flow to exergaming.

Our results can be directly compared to Limperos et al., (2011) as they used 2 methods of gaming to see if flow was achieved in either traditional gaming (play station2) or exergaming using the Nintendo Wii. It was hypothesised that the Wii would elicit greater levels of flow and enjoyment over traditional gaming due to the new aspect of gaming. However, results showed that it was in fact the traditional gaming (play station 2) which had greater levels of enjoyment and flow (control). These results partly compare to the current thesis in that the traditional exercise showed significantly greater levels of flow over time for autotelic experience (AE) clear goals (CG) and transformation of time (TT). A possible explanation for this could be due to the familiarity of movements used in the mirror-matched exercise as opposed to the new interface of the IREX™ system which may have taken participants longer to get used to. This current study illustrates the importance of measuring flow and acknowledges its relevance in exergaming literature; however, as the study was small in duration and time spent with the exergaming system, more longitudinal data is needed to fully explore flow in exergaming.

Table 4.1 14: Comparison of Flow during exergaming for healthy young adults compared to the results from the current thesis.

Study	Participants	Flow measures	Results
Current Study	Healthy young adults	Jackson and Marsh (1996) Flow state scale	Improvements over time for Autotelic experience, Clear Goals, and Transformation of Time
Thin et al., (2011)	Healthy Young Adults	FSS-2	Improvements over time for total flow for Challenge-Skill Balance and Action–Awareness Merging and Loss of self-consciousness.
Limperos et al., (2011)	Healthy Young Adults	Adapted flow from Jackson and Marsh (1996)	People playing traditional gaming (play station) significantly greater levels of enjoyment and flow (sense of control) over playing the Wii™
Sinclair et al., (2012)	Healthy Young Adults	Duel Flow	No statistical differences, nor where the participants "immersed" in the game.
Lai et al., (2012)	Healthy Young Adults	74-item EFSQ (exergaming flow scale)	More frequently and longer time durations for playing exergaming may increase the time spent in flow and also increase enjoyment.

In conclusion, the application of exergaming as a method of exercise shows some potential application to a healthy non-active population cohort with respect to acceptance and flow experience. However, further work should look at the effects of a longer- duration exercise programme to explore the acceptance and flow experience of the gaming environment in a healthy subject population and how flow experience facilitates the actual level of exergaming performance (Schuler and Brunner 2009). Larger-scale studies would also be advantageous in further work in order to generate more precise results for a healthy population.

4.24 Postural sway in non- active healthy adults.

The secondary aim of study one was to compare the effects of exergaming based training versus mirror-matched exercise on postural control. Tests of H_5 –H_8 hypothesis showed that for bipedal sway the H_5 null hypothesis could be accepted in that compared to mirror matched exercise, there was no statistically significant difference after a programme of exergaming in bipedal measures of postural sway. The only statistical difference that occurred was for bipedal MLSD over time, whereby both groups had a reduction in postural sway, but no statistical significance between exercise groups.

H_8 alternative hypothesis was accepted as compared to mirror-matched exercise, there was a statistically significant difference after a programme of exergaming in unipedal measures of postural sway: as AP (SD) and AP range in unipedal standing was smaller in the exergaming (IREX™) group indicating improvements in postural control as well as over time and interaction between time and exercise existed to statistical significance in favour of the exergaming group, showing reductions in postural movement in the AP direction. Although there were similar differences in unipedal ML sway and CoP velocity in that the exergaming group had reduced postural sway, these were not statistically significant. Analysis of the pelvic and neck movement data (collected via the XBUS™ system) showed similar trends to that of the force plate data. The ANCOVA analysis showed that during unipedal stance the

pelvic pitch (AP), (analogous to movements in the sagittal plane at L4 level) was significantly greater in the IREX™ group than the mirror-matched exercise.

The differences in AP excursion point towards a specific beneficial effect on balance of exergaming. Explanation for this may lie in either or both of the two main distinguishing features of the exergaming programme. The first of these is that exergaming is more task-orientated and thus more participatory, purposeful and engaging than performing each exercise in isolation as in the mirror-matched exercise, a feature that has been proposed as being important in improving the quality of balance exercises (Betker et al., 2006) . More purposeful movements may be experienced during the exergaming sessions as opposed to the mirror-matched exercise as the exergame allows interaction with the participant and a visual representation of how well they are doing (i.e. scores).

The second distinguishing feature of the exergaming programme is the animated virtual background in which participants watched themselves moving. People adjust their posture in standing in response to movement in the visual surround, which acts as a destabilising stimulus increasing postural stability during the task (Keshner and Kenyon 200) This destabilising effect has been demonstrated with a virtual visual surround (Keshner and Kenyon 2000; Tossavainen et al., 2003; Horlings et al., 2009). If present during the exergaming programme, and we did not assess this, such a destabilising effect would have added an extra balance training stimulus dimension to the exercises.

The postural adjustment is influenced by the direction of the movement in the visual surround (Burdet and Rougier 2007). It is thus possible for a visual surround with movement in one plane to selectively affect movement in that plane. Many of the games featured in the exergaming involved virtual objects and/or backgrounds moving in the sagittal plane towards and away from the participant. This could explain why the significant effects were in AP excursion. No statistically significant differences were observed between the groups in unipedal ML SD or ML range and there were no indications from their 95% CIs of trends

towards a difference that would have suggested a type II error. The unipedal CoP velocity was not significantly different between the groups post-intervention. However, it did show a trend with the 95% CI: zero was situated much more at the higher/lower extreme of the interval than the centre. Because CoP velocity includes movement in the AP and ML directions this probably reflects the effects on AP excursion and no effect on ML excursion. The implication, therefore, is that the visual component of the exergaming group selectively promoted movement in the AP direction.

Statistically significant differences between the groups were only observed in unipedal standing. This may have been because unipedal standing is inherently less stable than bipedal standing and, therefore, had more potential for improvement. This is particularly so for AP excursion, in which there is a relationship between unipedal and bipedal standing compared with ML excursion where the two are much more independent (Bisson et al., 2011).

The destabilising effect of movement in the visual surround has been linked with increased involvement of the trunk to control posture (Keshner and Kenyon 2000). This is consistent with our findings on neck and pelvic movements after exercise where the only statistically significant difference in post-intervention means was in unipedal pelvic pitch. The peak-to-peak pelvic pitch movement was greater after exergaming than after mirror-matched exercise suggesting that the improvements in AP excursion in the exergaming group may have been achieved by greater equilibrium-maintaining adjustments at the pelvic and lower torso regions. Essentially, movements at the pelvic region may have occurred which minimized the overall excursion of the entire system's centre of gravity. Although the mechanisms are still to be clarified, recent studies have shown that movement at the hip joint is an integral part of quiet standing balance (Winter et al., 1998). In the current thesis, it seems that the ability to make AP balance corrections at the pelvis may have improved in the exergaming group. The effects of movement in the visual surround are dependent on the degree and nature of the movements, and the relative effects of permutations of the different

factors are not known (Horlings *et al.,* 2009). We did not test this directly in our study and so the possibility of this mechanism in these specific circumstances, while plausible, it is speculative.

Bisson et al., (2007) found no significant effect on force platform measures of standing balance using the IREX™ system for exercise with a group of healthy older people. There are important methodological differences between the studies. As well as the age difference in comparison to our study the activities they used were restricted to one game, whereas in the current thesis a range of games were used. In contrast to our findings a different form of exergaming (Wii Fit™) was found to be less beneficial than mirror matched gym based exercise for balance (Bateni, 2011). However, the study was carried out on a very small sample of older people and the reports of differences were made on an interpretation of descriptive statistics rather than inferential analysis. In relation to young healthy studies Brumels et al., (2008) results showed similar results to the current study in that the two exergame based training (Wii fit™ and Dance Dance Revolution) showed significant improvements over traditional exercise in terms of postural sway reduction between groups. Veradakis et al., (2012) also used the Wii Fit™ to compare and 8 week training program using the Nintendo Wii compared to traditional balance exercises in healthy adults. Results differed from the current thesis and those of Brumels et al., (2008) as there were no statistical differences between exercise groups, yet significant improvements occurred over time in sway measures. A possible explanation for no differences could be due to the nature of the traditional training program as a lot of the training was predominantly carried out using one legged exercises, which is commonly used in balance training. Unlike our study, the movements were not matched in relation to the exergaming group, an obvious source of bias. Nitz et al., (2010) analysed the effects of a 10 week Wii fit™ training program in healthy women aged between 30-58 years old, the results showed significant improvements in unipedal stance with eyes open over time, however this study only looked at the Wii group, only, pre to post intervention which made results difficult to compare to the current

thesis. Nitz et al., (2010) also allowed participants to complete testing at home, which caused variations in the amount of adherence to the program.

Despite the exergaming group showing a significant improvement over time there was a degree of uncertainty with regards to the compliance rates of the home-based exercise. All subjects stated they had performed the home-based exercises over the two weeks; however, there was no objective way of quantifying whether or not they did. Therefore, compliance or the lack of this could be another factor influencing the outcome variables.

In conclusion, the application of exergaming as a method of exercise shows some potential application to a non- active healthy population cohort with respect to acceptance and flow experience. However, further work should look at the effects of a longer- duration exercise programme to analyse the acceptance and flow experience of the gaming environment in a healthy subject population and how flow experience facilitates the actual level of exergaming performance. Larger-scale studies would also be advantageous in further work in order to generate more precise results for a healthy population and use a longer training program with no home-based exercise.

4.25 Development of methodology for healthy adults.

The results from the current study show the potential of exercising in an exergaming environment over mirrored-matched exercise in relation to technology acceptance (UTAUT), and tentative results indicate the potential for using exergaming to improve postural control. It is possible that longer duration programs may increase the effect size and show more benefits in terms of acceptance and immersion of exergaming and also increased postural control. It was deemed necessary to conduct a second study using healthy active adults to analyse the true effects of exergaming for technology acceptance and postural control. Additionally a measure of physiological function was decided upon for study 2 in order to gain a further insight to whether exergaming can be physiologically challenging enough to elicit moderate levels of exercise intensity, by achieving 50-85% maximum heart rate (220-

age), in accordance to the American College of Sports Medicine guidelines (ACSM, 2005) . This was measured using heart rate (HR) as an objective measure and rate of perceived exertion (RPE) (Borg, 1982) as a subjective measure of physiological cost of exergaming and mirror matched exercise. Measuring the physiological cost of exergaming through HR and RPE will add to knowledge in the area of exergaming, as previously there is only one paper (O' Donovan et al., 2012) examining the physiological cost of the Kinect. However, this was only in one game (reflex ridge); therefore, adding multiple games and increasing the exercise intensity from week 1 to week 4 will give a greater levels of understanding behind the physiological cost of exergaming.

There was a key need to explore healthy active adults following the results from study one as no study had applied technology acceptance and flow over a long intervention period. There was also a need to explore the effects of exergaming on postural control compared to mirror matched exercise over a longer period of time to see if there was any significant advantages of using exergaming based exercise. The results from the postural control data indicate the potential for exergaming as a mean of balance training, however exercising only over a two week period may not be appropriate to all populations to show a reduction in postural sway. Therefore it was deemed necessary to extend the training program in duration, also a healthy active group were chosen, as it was felt they would adhere to the longer program more so than the non-active adults. According to guidelines for physical activity recommendations (ACSM, 2005) people should perform '*moderate aerobic activity for a minimum of 30 minutes, five days per week or vigorous aerobic activity for a minimum of 20 minutes, three days each week'.* Those classed as physically active optimally perform exercise 3-5 times per week already compared to non-active adults. As study 2 requires people to attend 3 exercise sessions of moderate to vigorous activity over 4 weeks (12 sessions in total) it was deemed necessary to use healthy active adults to maximise compliance. Literature has suggested that non-active adults find it difficult to change their lifestyle to include regular exercise and as a results adherence levels to exercise are often

low (Findoff et al., 2009), especially within the first 6 months of initiating exercise (Biddle & Mutrie 2008) and are less likely to start exercise compared to an active population. Therefore due to the progressive nature of study 2 it was believed that a healthy active population would be most appropriate to use.

4.26 <u>Summary</u>

Tentative results showed that exergaming elicited positive psychological response to technology acceptance and behavioural intention to use exergames in the future. The results from the UTAUT offer a novel application to exergaming research and need to be developed further. The levels of immersion into exergaming showed no statistical significance, which partly could be due to the short intervention and mastery of the exergame system.

Results indicate that exergaming can improve postural control over mirror-matched exercise, especially in the AP direction during unipedal standing. There was no significance established over time, however study 2 will use a more longitudinal exercise program in order to distinguish changes over time.

Postural control at the upper body showed increased movements at the pelvis during postural control in unipedal standing in the exergaming group, it was speculated that this increase in movement at the pelvic region may have occurred to reduce movement at the ground level (ankle) and resulted in minimizing the overall excursion of the entire system's centre of gravity. Although the study offers a novel application of using inertial sensors as a new method to assess postural sway. The results showed no correlation between force plate data and data from the inertial sensors which would indicate that quantitative posturography (force platform) is still one of the most reliable methods of assessing postural control.

5. METHODOLOGY

Study 2: A randomised controlled trial of physically active healthy adults acceptance (behavioural intention), flow experience (absorption in the activity) and postural control (before and after), exercising in: an exergaming environment (XBOX Kinect™) or mirror - matched exercise.

5.1 Aims

The primary aims were to;

1) To compare participants' acceptance (behavioural intention) of a two week exercise programme undertaken in either:

An exergaming environment XBOX Kinect™, or

Mirror-matched exercise.

2) To compare participants' flow experience (absorption in the activity) of a two week exercise programme undertaken in either:

An exergaming environment XBOX Kinect™, or

Mirror-matched exercise.

5.2 Subsidiary Aims

1) To compare the effects of exergaming based training versus mirror-matched exercise on postural control.

2) To compare the biometric intensity of the two methods of exercise in terms of mean Heart Rate (HR) and Rate of Perceived Exertion (RPE), Borg (1982) during the exercise.

5.2.1 Principal Aim: Hypotheses

H_9Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

H_{10}Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in levels of acceptance (behavioural intention).

H_{11}Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

H_{12}Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in levels of Flow (absorption in the activity).

5.2.2 Subsidiary Aim 1, Hypotheses

H_{13}Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

H_{14}Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming in unipedal measures of postural sway.

5.2.3 Subsidiary Aim 2

5.2.4 Hypothesis

H_{15}Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming for mean heart rate (HR).

H_{16} Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming for mean heart rate (HR).

H_{17} Null hypothesis;

Compared to mirror-matched exercise, there will not be a statistically significant difference after a programme of exergaming for mean rate of perceived exertion (BORG RPE).

H_{18} Alternative hypothesis;

Compared to mirror-matched exercise, there will be a statistically significant difference after a programme of exergaming for mean rate of perceived exertion (BORG RPE).

5.3   Study Design

A randomised controlled trial with two groups and factors;

Group 1 - exergaming with the Kinect™ system,

Group 2 – mirror -matched exercise

Factor 1 - between subjects, exercise group with two levels – Kinect™ and matched gym based exercise group.

Factor 2 - within-subjects, time with two levels – start (baseline) and end (post-programme).

5.4   Location and Governance

Ethical Clearance was sought from and granted by the School of Health and Social Care Research Governance and Ethics Committee at Teesside University (TU) (January 2011). (see appendix 13). The study was conducted in the Physiotherapy Research Laboratory, Constantine Building (TU).

5.5 Recruitment

An invitation email was sent via the TU Outlook system to all TU staff and research students (Appendix 14). Recruitment posters were also placed across the University (Appendix 15). People who replied were asked to read the participant information sheet (Appendix 16) and had the opportunity to ask GB any questions. Verbal and written informed consent was obtained from all those who decided to take part (Appendix 17).

5.6 Sample

Inclusion criteria: aged over 18, staff or students, able to read and write in English, and leading an active lifestyle. Healthy physically active adults were classed as those free from injury and illness and who already were taking part in 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week (ACSM, 2005). No previous experience of using the XBOX Kinect™.

Exclusion criteria included; inability, or any doubt of ability, to give informed consent, inability to comprehend and write English current, or history of (verified by self-report), any condition or injury which would contraindicate participation in the exercises under study, allergy to alcohol wipes and/or adhesive tape (self-report).

A convenience sample of 50 participants was recruited for the study (29 Male and 21 Female), participation was voluntary and no payment was given for taking part.

5.7 Instrumentation

5.7.1 Psychological Assessment

Participant's acceptance (behavioural intention) of the exercise environment was quantified using the UTAUT as employed in study one with minor changes to questions to reflect the use of the XBOX Kinect™ system (see appendix 18).

Flow state scale (Jackson and Marsh 1996) was quantified as in study one (see appendix 8).

5.7.2   Postural Sway

Postural sway data was recorded using the Kistler™ Force plate as in study one.

5.7.3   Surface Electromyography (SEMG)

To analyse muscle activation during standing balance a portable 8 channel Delsys™, Myometer, (IV, Boston, MA, USA) was used for the collection of surface electromyography (SEMG) of the lower limb for the dominant kicking leg. SEMG was recorded at 3 lower limb muscles at the Medial Gastronomies (MG) Tibialis Anterior (TA) and Soleus (S)[5].

5.7.4   Heart Rate Monitoring

 Heart rate during each exercise session was measured with and recorded by a Polar™ Heart Rate Monitor™ (FS2C). This comprises a recording watch (worn on the wrist) and a T31 coded chest strap (a soft hypoallergenic band (approximately L 15 cm W 4 cm) placed on the mid-line of the chest (below any clothing) which is held in place by an adjustable elasticated belt). The chest strap picks up heart rate which is transmitted wirelessly to the recording watch (see Image 9).

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[5] Surface electromyography (SEMG) was collected as an additional measure outside the scope of the thesis, and is documented in the thesis to facilitate the reader for replication of data collection techniques, but no results are presented here. See appendix 20 for full instruction of set up for SEMG.

Image 9: Polar™ Heart Rate Monitor (FS2C) and a T31 coded chest strap.

5.7.5   Rate of Perceived Exertion

Rate of perceived exertion (RPE) was recorded during exercise used on the Borg (1970) 6 - 20 point scale of subjective ratings of perceived exertion (see Appendix 19). RPE was collected immediately at the end of each exercise session, for both exercise groups, for overall estimates of the perceived exertion of the session on a whole.

5.7.6   Exergaming

The XBOX Kinect™ was used for the current study (see Image 10); this consists of; a Kinect sensor (Kinect head - the rectangular part - W110 x D25 x H15mm) and the base (W30 x

D30 x H15mm) and a widescreen Plasma screen (37, Hanaspree, Type T73B, Greyenstraat 65, Netherlands). The Kinect™ system employs infrared sensors to detect and track participant's movements which are used to generate an avatar which is projected - in real time - into the gaming environment which is displayed on the TV screen.

RGB Camera   3D Depth Sensors (infra-red)

Motorized tilt
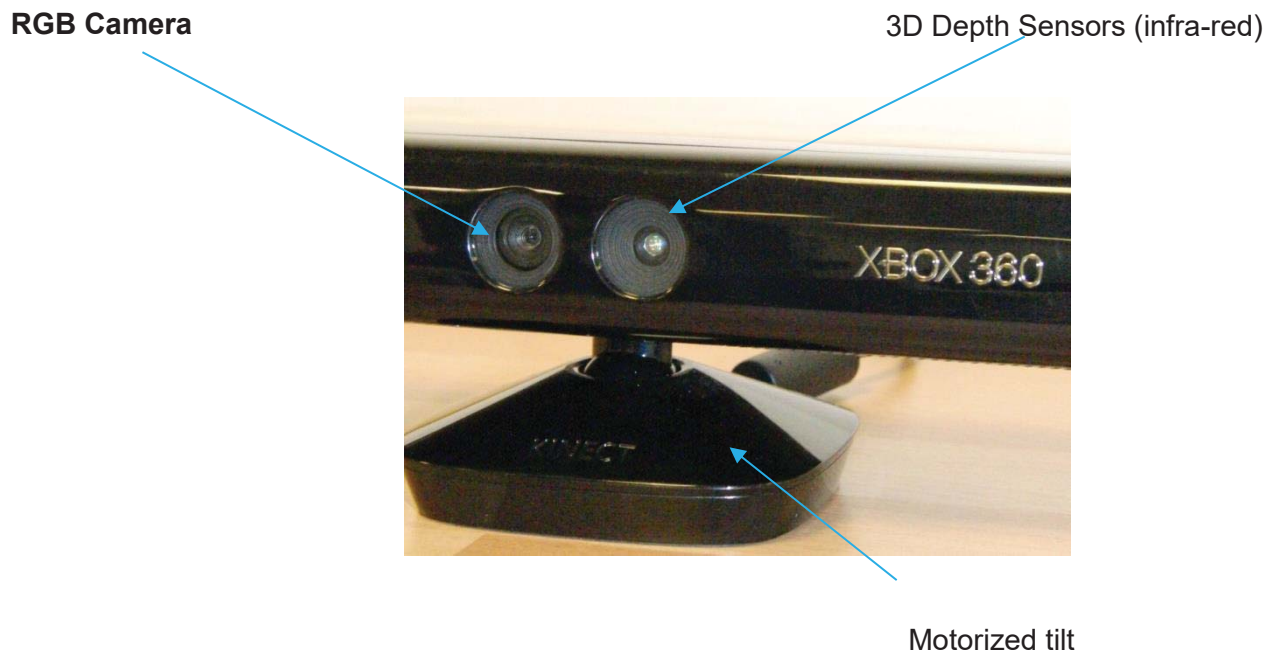
Image 10: Kinect™ infra-red sensor

5.8   Procedure

On arrival for data collection at the Physiotherapy Research Laboratory at TU all participants were given a copy of the Participant Information Sheet (Appendix 16) and asked and had answered any questions they had. They then signed the Informed Consent Form (Appendix 17). All effort was made by the GB to arrange the time of data collection to suite the participants. The room temperature was at approximately 25 degrees Celsius (°C) during all data collection and all participants were required to report to the laboratory in gym based clothing, preferably shorts and tee- shirt and no raised heels. All participants were asked to report to the laboratory three times a week for 30 minutes over a four week period (12 exercise sessions in total). After documenting Informed Consent demographic data including

weight (kg); height (cm); age (years); gender (M/F), dominant kicking leg and eye height were recorded for each participant (Table 5.1 3) eye height was recorded following the same procedure as study 1.

For the assessment of postural control participants had to remove their shoes and stand barefoot on the Kistler™ force plate, look directly ahead at the visual target (black circle) positioned 3 m from the centre of the force plate at eye height (Lafond et al., 2004; Raymakers *et al.,* 2005; Brumels *et al.,* 2008; Pinsault and Vuillerme 2008; Santos et al., 2008; Hatton et al., 2011) and to stand as still as possible (Zok *et al.,* 2008).

Data collection began when participants had adopted a static standing position with arms by their sides and the pelvis in line vertically with the head.

Participants were initially asked to stand as still as possible for 30 seconds standing on one leg, (their dominant - preferred kicking - leg) for five periods of 30 seconds trials. Between trials participants were asked to step off the force plate to allow calibration of the equipment - this acted as a rest period of 30 seconds. The same procedure was followed for each of five trials. During all balance trials GB stood behind the participant in order to assist should a participant lose their balance and participants performed each test with their eyes open.

 Following postural control assessment the Kistler™ force plate was wiped with a hard surface bactericidal sterilising wipe between participants.

Participants at this point put their shoes back on and were asked to wear a Polar™ Heart Rate Monitor. This was fitted by the participants themselves with simple instructions. If participants needed to they asked GB for help in adjusting the size of the belt. Participants were asked to wear the HR monitor during all exercise sessions.

Participants were then randomised by blind-card allocation (picking a sealed opaque envelope) to either the exergaming (Kinect™), or mirror- matched exercise.

In both exercise groups the exercise sessions were individual, not group sessions. At all sessions and for both groups GB always demonstrated the exercises and taught participants to perform them in a correct manor. Prior to any exercise taking place GB showed all participants' examples of the exercises whether it was in the Kinect™ environment or mirror matched gym based exercise. Following the initial exercise demonstration all participants completed the version of Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire for their specific exercise group (see appendix 18). The questionnaire was completed prior to any exercise, but after the demonstration, to capture participant's initial views and thoughts about the exercise environment they had been allocated to. HR data was recorded and analysed as an objective indication of the biometric intensity of the two types of exercise environments at each session. Mean HR was calculated for every exercise session to allow between exercise comparisons. Participants were also asked to give their mean RPE, as a subjective measure of exertion, at the end of every exercise session.

5.9 Exercise matching and progression

The main purpose of having a gym based exercise group which mirror matched the movements in the exergaming group was to investigate any potential effects of using the same method of exercise with and without virtual stimuli. In the mirror-matched exercise group sessions participants were required to perform balance based exercises which mirrored the activities and demands of the Kinect™ games. The exercises were matched in terms of sequence, intensity, duration and mode of exercise by adopting open and closed chain limb movements of the same range and loading as was demanded in the games in the Kinect™ group (see Table 5.1 1 for full comparisons of movement during the Kinect and mirror-matched exercise group). In both exercise conditions GB demonstrated the exercises and the movements required.

Table 5.1 1: Comparison of movement patterns between exergaming (Kinect) and mirror-matched exercise

Games	Exergaming Instruction	Mirror matched Instruction	Movements required
Reflex Ridge	Steering a cart along a track, avoiding obstacles by jumping and landing on two feet, squatting down, and using full body movements jumping from left to right to avoid barriers and collect points.	Jump up and down on the spot, taking off and landing in the same position (2 footed). In between jumping, perform a squat, keeping your back straight and not bent. Move your full body from left to right when instructed to do so as fast and safely as possible. Only under instruction from GB alternate the movements.	Full medial and lateral weight shifting. Vertical jumping and squatting low.
River Rush	Steering a river raft boat down a rapid to collect points by moving from left to right, reaching out to the sides to grasp points and jumping up and down (taking off and landing on two legs).	Move your whole body from left to right in a fast and safe manor when instructed. On the commend of GB jump, taking off and landing on two feet, either straight up and down or jumping to the left or right. When jumping reach lift both arms up and in the direction of movement (i.e. left or right).	Full medial and lateral weight shifting of the centre of gravity over base of support.
Boxing	Punch and kick as many virtual targets in a specific time (1 minute).	Lift both arms up in front of chest and clinch your fingers into a fist position. Using alternative arms punch forward, and punch across your body with twisting of the torso at the same time. For kicking movements kick straight in front at waist height, then alternatively kick across the body, requiring torso twisting.	Anterior and medial-lateral weight shifting of the centre of gravity over base of support. Concentric and eccentric hip and shoulder flexion and extension, with torso twists.
Super Saver	Reaching up and forwards and moving legs and torso from side to side to block a ball from going in the goal	Lift both arms up and forwards and grasp your fingers and the drop them back down, move torso from left to right and move legs alternatively to the side.	Full medial and lateral weight shifting of the centre of gravity over base of support. Concentric shoulder flexion, finger flexion and hold and eccentric flexion back to neutral.
Target Kick	Kick virtual ball into the targets as many times as possible, standing on alternative legs to kick the ball.	Start in a normal neutral standing position, (two feet on the ground); alternatively produce kicking movements with each leg.	One legged standing with hip flexion and extension.
Bump Bash	Avoid as many targets thrown over a volleyball net by moving left or right, squatting down or jumping up to avoid the obstacles.	Start in a normal neutral standing alternatively produce squats, followed by jumping and moving to side to side as quickly and safely as possible. Under the instruction of GB the movements were randomised and shouted out to the participants.	Full medial and lateral weight shifting. Vertical jumping and squatting low.

A stop watch was used to time the games for each session and GB also actively took part in the sessions where necessary by giving directions of movement such as left and right and when to jump and squat in order to stimulate games such as reflex ridge (Kinect adventures).

The intensity of the exercise was only increased each week if there was a mutual agreement by GB and participants to do so. At no time did GB try to influence any participant to increase the intensity of the games. GB asked participants if they wanted to increase the intensity levels, based on the previous sessions mean HR and RPE. If participants were struggling with the previous session i.e. they had HR at or above 80% of their HR max[6] or their RPE was 15 or above they were not invited to consider increasing intensity. Intensity was increased by adding wrist and /or ankle weights. Firstly by adding 1kg weights leg weights, increasing to 2kg leg weights in week 3 and 2kg leg weight plus 1kg wrist weights in week 4 (see Image 23 for example of a subject with weights). With the increase in intensity, GB also asked participants if they wanted to increase the level of the exercise in both environments, this was performed by changing the exergaming game levels, which ultimately meant and increase in the number of repetition of movement played in each game. In order to maintain consistency through both methods of exercise GB noted down the mean number of movements during each game at different levels to enable consistency in the number of repetitions during the mirror-matched exercise. In one of the exergames a wobble board (see Image 11 for example of wobble board) was used in weeks 3 and 4 if the participants felt comfortable to do so. This was only applied to one game, (super saver) which required a more static standing position. During both modes of exercise GB gave verbal encouragement to make sure that the sessions were as closely matched as possible.

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[6] HR max calculated by 220 beats per minute (bpm) – age = max HR.

Image 11: Example of a wobble board (Boso ball).

5.9.1 **Exergaming**

Participants who were randomized into the Kinect™ group were asked to wear their normal shoes; no other equipment was needed as the Kinect™ tracks participants movements through an infra- red sensor built into the system.

Participants stood 6 foot away from the television (TV) monitor in order for a virtual avatar (a computer generated representation of the participant) to be created. A general male and female avatar was created by GB prior to any testing; as allowing participants to choose their own avatar often results in people selecting an ideal self-image of them (Pace, 2008) and may not be truly representable of themselves. The change from the IREX™ in study 1 to the Kinect in study 2 was due to technological advancements. The IREX™ system had become dated by the commencement of study 2 (2010), which lead to using the Kinect. The Kinect™ was chosen as it uses the same Gesture technology to enable a controller free exergaming system, (similar to that of the IREX™). The Kinect™ system positions the participant's avatar within a playing area based on their height (see Image 12). The room was also free

from any external devices (tables, chairs) which may have interfered with the image detection.

Image 12: Diagram representing a participant using the Kinect™ system.

Participants were required to participate in three Kinect™ exergaming games which were specifically focused on balance training - Kinect sports™, Kinect adventures™ and Your Shape™.

To familiarise people with the exergaming system the first session acted as an introduction to the games using "mini games" from the Kinect™ Sports game (see Images 13-16 for examples of mini games and movements required). Mini games are short games lasting for 1 minute in duration and are based on the 5 main sports in the Kinect sports games (soccer, boxing, athletics, volleyball, and bowling). A familiarisation session included participants using the gaming device themselves after initial instruction from GB.

5.9.2   Mini Games

Game 1-Target Kick (mini game) - participants kicked the ball into the targets in the goalkeepers net (see Image 13). At the start of the game participants stood in a neutral standing position with both feet on the ground with the aim of getting as many balls in the target. Participants alternated kicking the virtual ball with their dominant and non-dominant leg, more so participants stood predominantly on their non-dominant kicking leg. No instruction was given by GB as to which leg they should use.

Image 13: Target Kick

Game 2- Super Saver (mini game) - Participants had to save as many shots as possible using any part of their body (see Image 14). At the start of the game participants stood in a static upright position with both feet on the ground with the aim of saving as many shots as possible. The participants were required to move their upper and lower body (feet, torso and arms) in both medial and lateral directions in order to save the balls from getting into the net.

Image 14: Super Saver.

Game 3- Bump Bash (mini game) - participants had to avoid as many targets thrown over a volley ball net by moving left or right or squatting down or jumping up (see

Image **15**). At the start of the game participants stood in a static upright position with both feet on the ground then they had to move their whole body in both medial and lateral directions and to squat down to avoid being hit by the flying objects.

Image 15: Bump Bash.

Image 16: Body Bash (mini game) - participants had hit the ball when it came over the volleyball net with the body part called out (head, foot or hand), (see Image 16). At the start of the game participants stood in a static upright position with both feet on the ground, then they were required to hit the volleyball with their head, feet or hands (either left or right for feet and hands depending on the direction of the ball).

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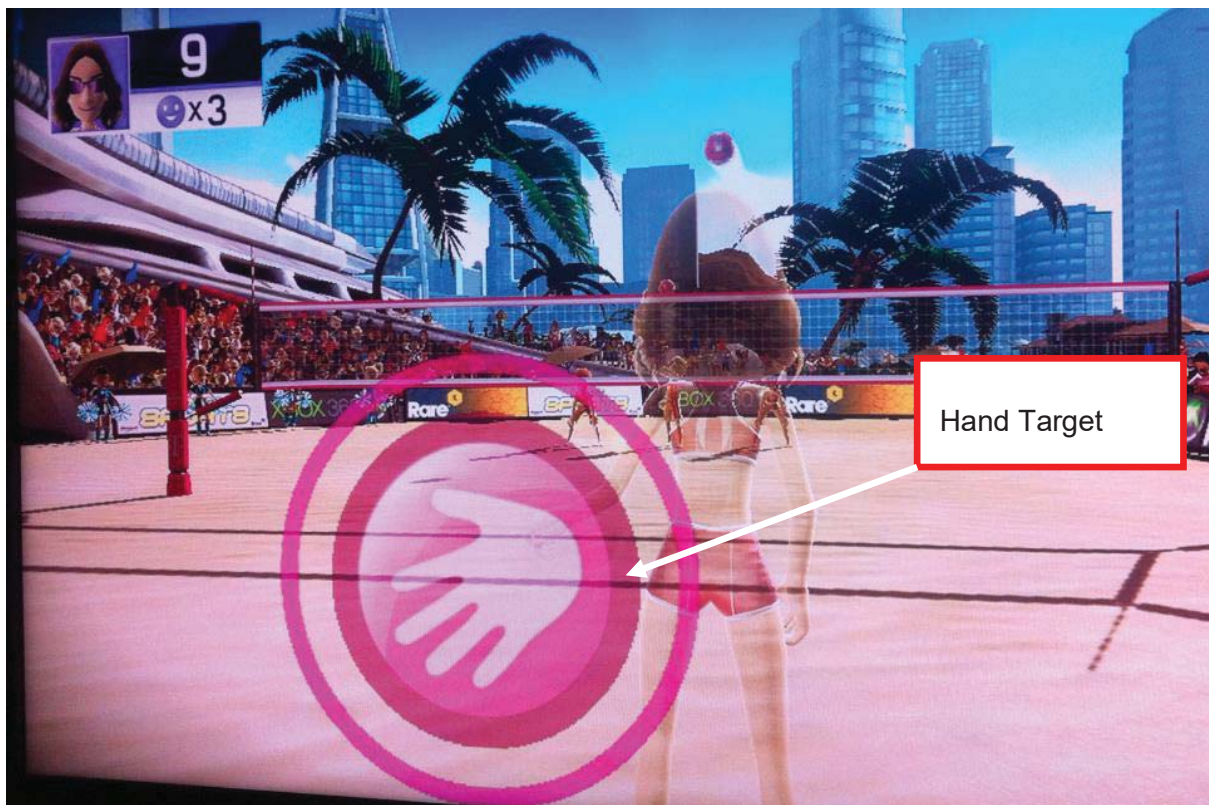
Image 16 Body Bash

5.9.3 Kinect™ sessions

Over the course of the four weeks of exercise, participants played a range of balance based games. Each session began with two warm up games; Boxing (Kinect™ Sports) and rally ball (Kinect™ adventures) game, which were played for 3 minutes each (see image 17 and 18). Following the warm –up games the main exercise session began with each game played for 4 minutes (24 minutes in total), (see images 19-22 for full details of games and range of movements required).

Warm-up Game 1- Boxing- participants had to avoid punches to the head and stomach by moving their upper body and also to knock their virtual opponent out as fast as they could (see Image 17). At the start of the game participants stood in a static upright position with both feet on the ground then they had to move their upper body (torso and arms) to block shots from their virtual opponent and also strike their opponent in the head and torso by punching with either arm.

Image 17: Screen shot of boxing game (Kinect Sports)

Warm-up Game 2- Rally Ball - participants had to hit as many target as they could during an allotted time by throwing balls down a bowling alley (see Image 18). At the start of the game participants stood in a static upright position with both feet on the ground then they threw a ball (virtual) down the bowling alley in order to hit the targets at the bottom of the alley, when the balls hit the targets, then this would mean that the balls would rebound of the target and come back towards the participants. At this point the participant used any part of their body (head, torso, upper and lower body) to deflect the balls back down the bowling alley to hit the targets, the game finished either when all of the targets had been smashed with the virtual balls of when time had ran out.
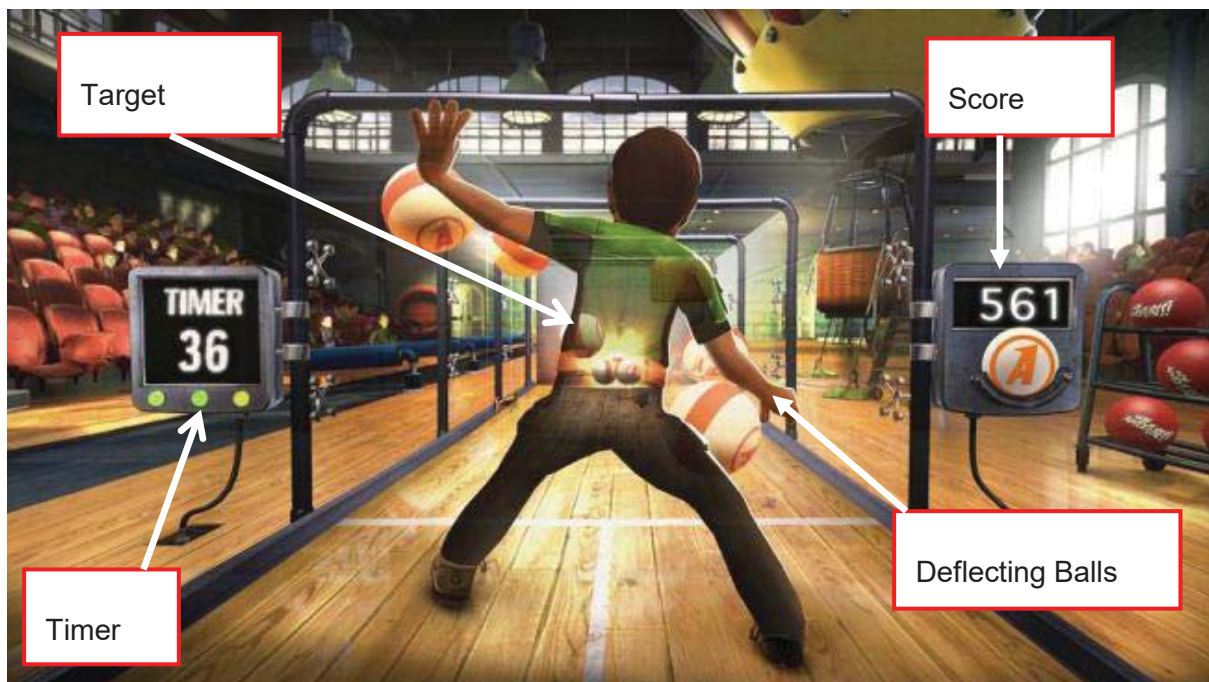
Image 18: Screen shot of Rally Ball (Kinect Adventures)

5.10 Main Intervention Games

Game 1- Reflex ridge- Participants steered a cart along a track by moving their body from left to right and jumping up and down (taking off and landing on two legs). At the start of the game participants stood in a neutral standing position, with their arms raised straight in front of them as if they were grabbing onto bars (see Image 19). The aim of the game was to collect as many coins as they could by: jumping over, or, squatting underneath barriers (see

Image **20**), using their upper body to reach out in both medial and lateral directions depending on the position of the coins and moving their body to either the left or right to avoid barriers.

Image 19: Reflex ridge starting position
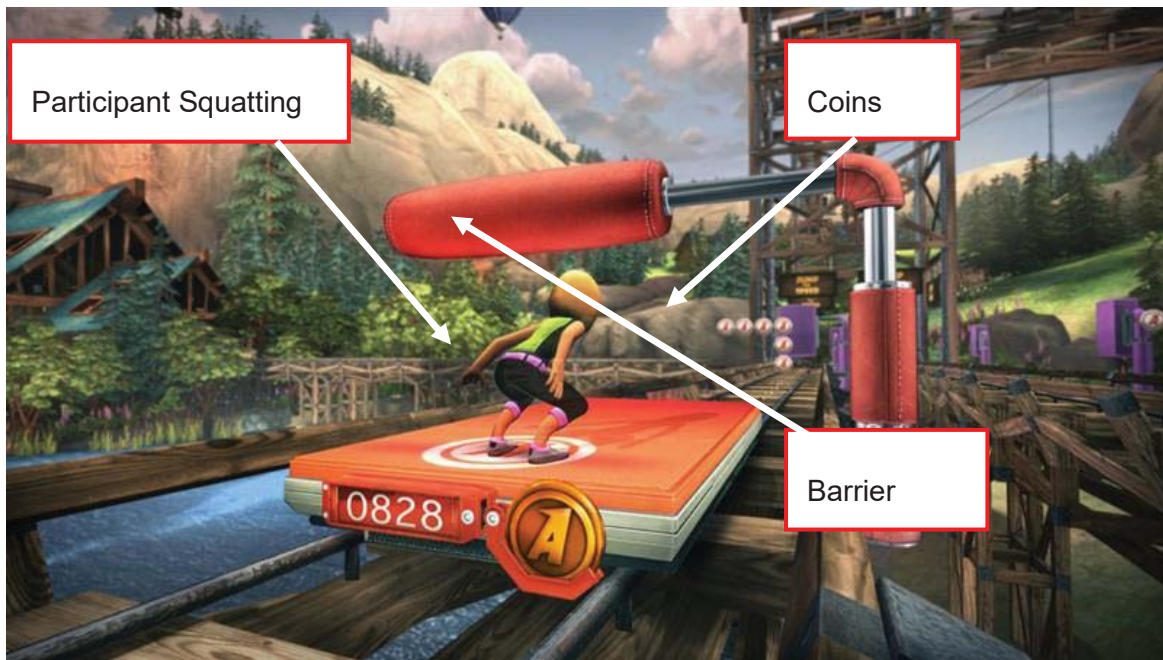
Image 20: Reflex Ridge (squatting position).

Game 2- River Rush- Participants steered a river raft boat down a rapid to collect points moving their body from left to right and jumping up and down (taking off and landing on two legs). At the start of the game participants stood in a neutral standing position, and had to jump up and land on two feet to start the game (see Image 21). The aim of the game was to collect as many coins as they could by steering the raft down the rapids collecting points (coins) on the way. Participants used their upper body to reach out in both medial and lateral directions for the coins and their lower body in medial and lateral directions to steer the raft, jumping movements were also required when coins were positioned higher up.
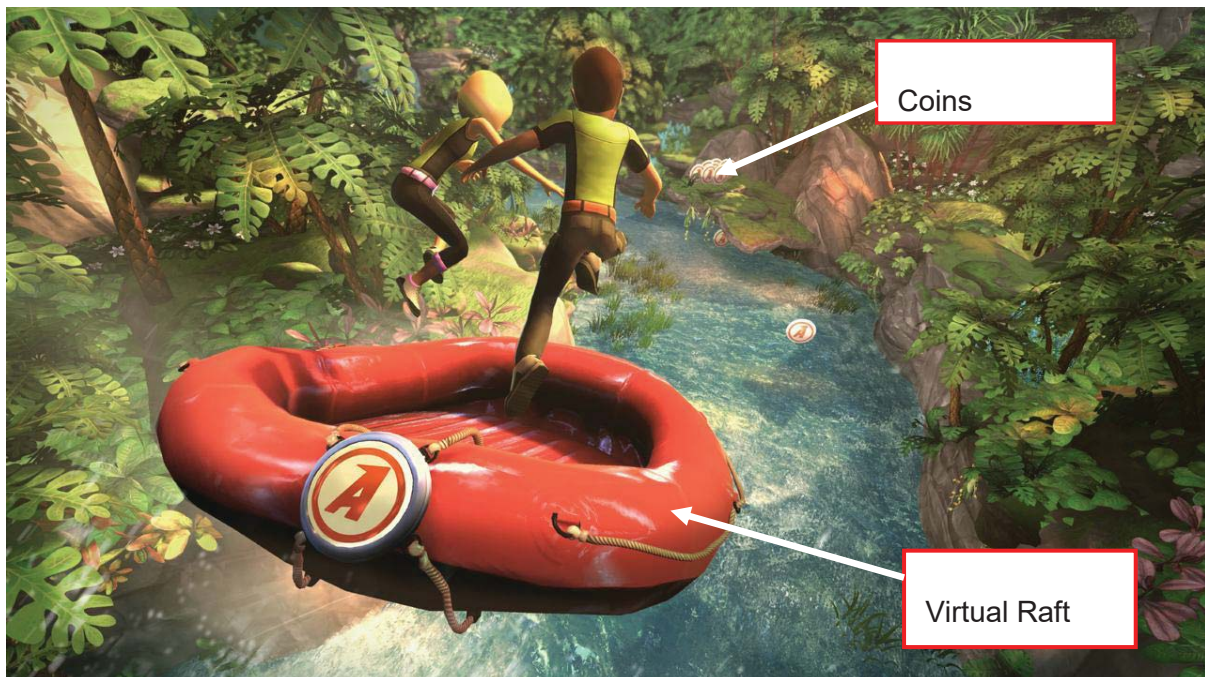
Image 21: River Rush (Participant jumping to get stars).

Game 3- Boxing (Your shape)-participants had to hit as many targets as they could in a specific time (1 minute), using upper and lower body movements (see Image 22). At the start of the game participants stood in a static upright position with both feet on the ground with the aim punching and kicking the targets in an accurate manor. The participants were required to move their upper and lower body (feet, torso and arms) by punching and kicking straight forward and across their body involving mixture of upper and lower body striking movement in all three planes of motion (sagittal, frontal and transverse)..

Image 22: Kinect Your Shape boxing game

Game 4-6 were Super saver, Target Kick and Bump Bash, full explanation of the games can be found in the practice session (pages 200-202).
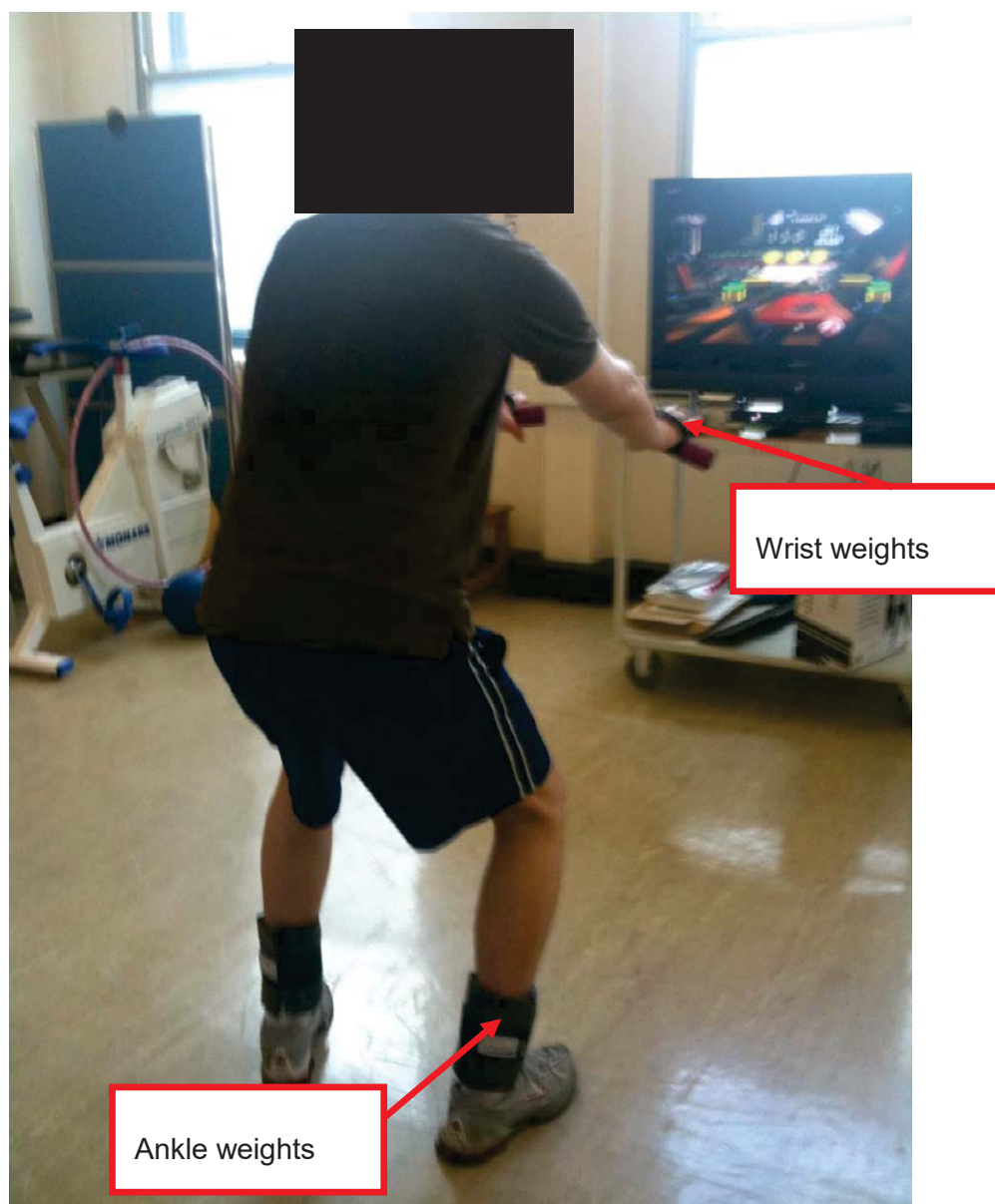
Image 23: Example of a participant using ankle and wrist weights whilst playing the Kinect™.

5.11 Data reduction

Mean HR and RPE (Borg 1985) were taken at the end of each exercise session and the mean HR and PRE data was compared between the exercise groups and over time. RPE scale is a 14 point scale ranging from 6 which is no exertion at all to 20 which is maximal exertion. RPE is widely used in research as a subjective indication of exertion (López-Mi˜narro and Rodríguez 2009; Eston et al., 2009).

[7]Outcome measures of UTAUT, and postural control using the Kistler™ force plate, were measured in before the first and after the last exercise sessions to compare both within-subjects factor (time with two levels – the start of the four week exercise programme (baseline) and the end of the programme (post-programme), and, between-subject factor (exercise (Kinect™ versus mirror-matched exercise).

The CoP AP and ML range and SD (mm) were calculated automatically using the force platform Bioware software package. CoP velocity was calculated using previous methods (Raymakers *et al.,* 2005) after low-pass filtering of the raw data at 10Hz. Mean CoP was calculated according to Raymakers formula for CoP, where Vd is displacement and n is number of samples.

CoP velocity (mm s-1): Σ Vd

$$N$$

As participants performed five repetitions of quiet standing balance both for unipedal stance at baseline and post exercise, a mean value of the five trials was calculated for statistical analysis. At a minimum the mean of 3 trials were analysed - participants for whom only one data point was obtainable were excluded from the analysis.

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[7] Only Flow state scale was taken post exercise after the first session.

5.12 Statistical Analysis

Data were analysed using Statistical Package for the Social Sciences Version 18 for Windows (SPSS, Chicago, IL, USA). Outcome measures were analysed as randomised following intention to treat principles; by separate analysis of covariance (ANCOVAs), comparing the post-test differences between the groups, with baseline values comprising the covariate with an alpha level set at 0.05. Within-subject differences of exercise over time for each measurement were investigated with a mixed analysis of variance (ANOVA). The tables of results will report means with standard deviations and 95% confidence intervals of the differences between exercise groups as well as the p-value.

Multiple regression analysis was performed for the UTAUT questionnaire, only, using behavioural intention as the dependant variable and performance expectance, effort expectancy, and social influences as the covariates in order to analyse if any of the covariates can significantly predict behavioural intention.

The aim of this investigation was to explore whether exercising in a virtual environment compared to mirror matched exercise with no virtual stimuli had any effect on technology acceptance and balance in a non-active healthy population. The statistical analysis as described above was believed to be the best method to achieve this as the ANCOVA allowed between group comparisons and the mixed ANOVA allowed the analysis of any differences over time to be analysed.

5.12.1 Reliability Testing

The thesis reports reliability between each psychological subscale for both the UTAUT and FSS using Cronbach's coefficient alpha (α). According to Nunnally (1978), 0.70 is an acceptable value to demonstrate reliability. Variables deemed unreliable will be excluded from any further analysis.

5.13 Results from a randomised controlled trial of physically active healthy adults acceptance (behavioural intention), flow experience (absorption in the activity) and postural control (before and after), exercising in: an exergaming environment (XBOX Kinect™) or mirror-matched exercise.

5.14 <u>Introduction</u>

This chapter will present the results from study 2 for the effects of exergaming verse mirror-matched exercise for acceptance, immersion and postural control. From a psychological perspective the results from the UTUAT, flow state scale and RPE will be analysed and reported. Data collected simultaneously for EMG and postural control will be presented over a 30 second time interval. Heart rate will be presented in context to the physiological effects of both types of exercise.

5.15 <u>Healthy Subjects</u>

A convenience sample of 50 healthy adults, were recruited from TU staff and students. Three subjects were excluded from the study as shown in the CONSORT diagram (Table 5.1 2). One person attended the session with a prosthetic leg and therefore did not meet the inclusion criteria. The other two subjects failed to attend due to injury. Because the equipment failed to capture data sufficiently on 3 participants only 44 subjects were analysed a mean (1SD) age 33.80 (12.7) years. Data from 23 participants were available for analysis in the exergaming group (age mean 37.44; 1SD 13.95; minimum-maximum 23-62; 12 men and 11 women). In the mirror-matched exercise there were 21 participants (age mean 29.90; 1SD 10.09; minimum-maximum 22-58; 12 men and 9 women). Descriptive statistics of demographic data are reported in Table 5.1 3.

Study 2 followed the same methods of statistical analysis used for healthy non – active young adults in this thesis.

CONSORT Flow diagram

Enrolment

Assessed for eligibility (n=50)

Excluded (n=3)

Amputee (n=1)

Injury (n=2)

Randomized (n=47)

Allocation

Allocation to intervention (n=24)

- Received allocated intervention (n=24)

Allocation to intervention (n=23)

- Received allocated intervention (n=23)

Follow-up

Lost to follow-up (n=0)

Lost to follow-up (n=0)

Analysis

Analysis (n=23)

- Excluded from analysis (error in capture data)(n=1)

Analysis (n=21)

- Excluded from analysis (error in capture data)(n=2)

Table 5.1 2 CONSORT flow diagram of recruitment and exclusion criteria.

Table 5.1 3 Demographic data for healthy subject population.

Gender	Age (years)	Height (cm)	Weight (kg)	Dominant kicking leg
	Mean (SD)	Mean (SD)	Mean (SD)	
24 (M) 20 (F)	33.80 (12.7)	172.90 (11.91)	75 (15.83)	42 (R) 2 (L)

5.16 Psychological Analysis of Exergaming verse mirror matched gym based exercise with no virtual stimuli with no virtual stimuli

5.16.1 Effects of independent variables on technology acceptance reliability.

Table 5.1 4 shows the reliability analysis was performed on the UTAUT subscales at before and post exercise testing to assess internal reliability between the subscales.

Internal consistency was assessed following the same analysis as in study one (Cronbach's Alpha). Before exercise results showed that for social influences (SI) and facilitating conditions (FC) baselines scores failed to reach reliability set at 0.70 (Cronbach's Alpha) however, due to high post exercise reliability scores SI and FC remained in the analysis of the data. Internal alphas consistency ranged between 0.63 to 0.95 at pre exercise and 0.71 to 0.92 at post exercise showing good internal consistency between the UTAUT subscales.

Table 5.1 4 Reliability of UTAUT using Cronbach's Alpha (α)

Subscale	Before exercise Cronbach's alpha	Post-exercise Cronbach's alpha
PE	0.87	0.90
EE	0.90	0.92
SI	0.63	0.83
FC	0.66	0.71
BI	0.95	0.90

5.16.2 Reliability of Flow State Scale (FSS)

Reliability analysis for FSS was performed using the same reliability analysis of UTAUT using Cronbachs alpha (α) > 0.70. All data for baseline and post exercise testing showed data to be reliable for FSS (see Table 5.1 5). Internal alphas consistency ranged between 0.70 to 0.90 at before exercise and 0.77 to 0.88 at post exercise showing good internal consistency between the flow subscales.

Table 5.1 5 Reliability analysis of FSS

Subscale	Before exercise Cronbach's alpha	Post-exercise Cronbach's alpha
AE	0.82	0.84
CG	0.82	0.78
CB	0.79	0.84
CT	0.70	0.82
PC	0.86	0.84
UF	0.85	0.86
AM	0.90	0.77
TT	0.73	0.88
LS	0.76	0.78

5.17 Effects of independent variables on technology acceptance

5.17.1 The effects of technology acceptance between exercise groups.

Overall levels of acceptance where higher at the end of the exercise program for the Kinect™ group compared to the mirror matched gym based exercise with no virtual stimuli as shown in Table 5.1 6

Table 5.1 7 shows between exercise groups (ANCOVA) and within- group change over time (mixed ANOVA) results. The ANCOVA shows higher levels of acceptance as performance expectancy (PE) was significantly higher between exercise groups, with before exercise values acting as the covariate, $F (1, 44) = 6.99$, $p = 0.012$, $\varepsilon^2 = 0.15$. As well as PE, Social influences (SI) $F (1, 44) = 13.35$, $p = 0.001$, $\varepsilon^2 = 0.25$, and behavioural intention (BI) $F (1, 44) = 14.91$, $p < 0.001$, $\varepsilon^2 = 0.27$ showed a significant difference occurring between exercise groups, with higher mean values occurring in the Kinect™ group which would indicate a greater levels of acceptance towards exergaming rather than mirror-matched exercise. EE and FC did not show any statistical significance occurring between groups, nor were and 95% CI close to zero.

The results from the mixed ANOVA showed that over time there was a significant improvement in performance expectancy (PE), $F (1, 44) = 5.35$, $p = 0.03$, $\varepsilon^2 = 0.11$, and a significant improvement in effort expectancy (EE), $F (1, 44) = 8.83$, $p < 0.01$, $\varepsilon^2 = 0.17$ in the exergaming group (95% confidence limits closer to zero) indicating larger differences occurring. None of the other technology acceptance variables showed any significant differences over time.

Statistical significant differences were found for social influences $F (1, 44) = 5.76$, $p = 0.02$, $\varepsilon^2 = 0.12$, and behavioural intention $F (1, 44) = 11.52$, $p < 0.001$, $\varepsilon^2 = 0.21$ when a time * exercise interaction effect was ran. Showing that for both variables, the Kinect™ exercise group showed higher mean values post exercise for SI and BI, whereas, the mirror-matched

exercise had a reduction in mean scores. For SI mean scores ± 1SD were 5.25 (1.02) at pre exercise, compared to 5.68 (1.21) post exercise, whereas the mirror matched gym based exercise group with no virtual stimuli means scores were 4.88 (1.26) and 4.24 (1.20) respectively. Likewise for BI mean scores for the Kinect were 5.25 (1.52) at pre exercise and 6.13 (1.27) post exercise, compared to the mirror-matched exercise 5.51 (1.29) to 4.86 (1.19).

Table 5.1 6: Descriptive statistics (Mean ± SD) for technology acceptance variables

Variable	Before exercise		Post-exercise	
	XBOX Kinect™	[8]Mirror-Matched	XBOX Kinect™	Mirror-Matched
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Performance Expectancy (PE)	5.05 (1.12)	5.17 (1.47)	5.93 (1.16)	5.19 (0.94)
Effort Expectancy (EE)	5.13 (1.61)	5.38 (1.02)	6.08 (1.12)	5.63 (0.97)
Social Influences (SI)	5.25 (1.03)	4.88 (1.59)	5.65 (1.21)	4.24 (1.20)
Facilitating Conditions (FC)	5.90 (1.39)	5.79 (1.09)	5.88 (1.30)	5.17 (1.32)
Behavioural Intention (BI)	5.51 (1.53)	5.50 (1.29)	6.13 (1.26)	4.86 (1.19)

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[8] Note mirror-matched stands for mirror matched gym based exercise with no virtual stimuli

Table 5.1 7**:** Within-group change over time mean differences (95% CI) and adjusted post – intervention between group difference (ANCOVA) for UTAUT.

	Within-group change over time (Mixed ANOVA)		ANCOVA Adjusted post-intervention difference between groups
	XBOX Kinect™	**Mirror-Matched**	**XBOX Kinect™- Mirror-Matched**
	Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Performance Expectancy (PE)	-0.89 (-1.33 to -0.43)*	-0.02 (-0.72 to 0.67)	0.78 (0.19 to 1.38)*
Effort Expectancy (EE)	-0.94 (-1.52 to -0.37)**	-0.25 (-0.86 to 0.36)	0.53 (-0.70 to 1.12)
Social Influences (SI)	-0.40 (-0.94 to 0.13) **	0.64 (-0.10 to 1.39)	1.32 (0.59 to 2.05)**
Facilitating Conditions (FC)	0.01 (-0.33 to 0.36)	0.62 (-0.25 to 1.48)	0.67 (-0.08 to 1.42)
Behavioural Intention (BI)	0.88 (-1.42 to -0.35)***	0.65 (0.14 to 1.45)	1.36 (0.65 to 2.01)***

* Significant *p* < 0.05 level; ******Significant *p* < 0.01 level *** Significant p<0.001

5.17.2 Multiple regression analysis for technology acceptance

Multiple regression results are presented in Table 5.1 8. Firstly only direct effects were regressed (PE, EE, FC, age, intervention and gender) against BI and were statistically significant at both pre exercise $F_{(7, 36)} = 7.17$, $p < 0.01$, adjusted $R^2 = 0.50$ at before exercise and also at post exercise $F_{(7, 36)} = 15.93$, $p < 0.01$, adjusted $R^2 = 0.71$. Before exercise adjusted R^2 indicates that 50% of behavioural intention can be explained by the independent variables (PE, EE, FC, age, intervention and gender). However, post exercise behavioural intention can be explained by 71 % of the time by the independent variables (PE, EE, FC, age, intervention and gender).

When the covariates where split separately performance expectancy $t_{(43)} = 2.67$, $p < 0.01$ significantly predicted behavioural intention at pre exercise and performance expectancy $t_{(43)} = 2.02$, $p = 0.05$ and social influences were significant predictor $t_{(43)} = 2.84$, $p = 0.007$ of behaviour at the end of the exercise intervention (see Table 5.1 8).

When interaction terms were included in the model, adjusted R^2 values stayed the same at before exercise 0.50 with R^2 change accounting for 17% in variance when adding the additional interaction effects; however this was not at a significant level. Post exercise adjusted R^2 values increased from 0.71 to 0.75 with R^2 change accounting for 12% in variance, again this was not significant. The results showed that by adding the interaction terms did not significantly contribute to strengthening the model. A possible explanation for no significance could be due to multiple predictors (15) in the interaction effect actually made the model weaker. In terms of the main effect of intervention and interaction effects with the technology acceptance variables they were not significant. Nor was any statistical significance established between age or gender at pre or post exercise. Performance expectancy was the strongest predictor of behavioural intention.

Table 5.1 8: Multiple regression for UTAUT

	Before Exercise		After Exercise	
	D Only β	D +1 β	D Only β	D +1 β
R^2	***0.58	0.75	***0.76	0.88
Adjusted R^2	0.50	0.50	0.71	0.75
R^2 Change		0.17		0.12
Performance Expectancy (PE)	*0.37	-0.28	*0.25	0.16
Effort Expectancy (EE)	0.19	-1.47	0.14	-0.30
Social Influences (SI)	0.12	0.29	**0.40	-0.03
Facilitating Conditions (FC)	0.26	0.33	0.16	-0.72
Age (AGE)	-0.06	-0.56	0.14	1.05
Gender (GDR)	-0.01	-0.49	-0.07	-0.39
Intervention (Int)	0.07	-0.33	-0.03	-0.65
PE X GDR		0.37		0.29
EE X GDR		1.10		0.15
SI X GDR		-0.22		0.78
FC X GDR		-0.78		-1.01
PE X AGE		0.53		-0.06
EE X AGE		0.40		0.01
SI X AGE		-0.46		-0.57
FC X AGE		0.45		1.57
PE X Int		-0.25		-0.12
EE X Int		0.27		0.18
SI X Int		0.29		0.14
FC X Int		0.18		0.72
AGE X GDR		-0.24		-1.06
AGE X Int		-0.38		0.36
GENDER X Int		0.54		0.66

Note D Only: Direct effects only; D +1: Direct effects and interaction terms. Greyed out cells are not applicable for specific column *$p<0.05$ **$p<0.01$

***$p<0.001$.

5.18 Effects of independent variables of Flow experience

5.18.1 The effects of independent variables of Flow experience between exercise groups.

Overall, levels of flow were high for both exercise groups (see Table 5.1 9). Post exercise test all of the variables improved apart from concentration of task which mean scores dropped slightly in both exercise groups. In the mirror-matched exercise group, transformation of time also got worse over the duration of the exercise from the start to the end of testing.

Table 5.1 10 shows the between exercise groups difference (ANCOVA) and within-group difference over time (mixed ANOVA). The ANCOVA results showed differences between groups in favour of the Kinect™ group for concentration of task F $(1, 44)$ = 5.16, p = 0.03, ε^2 = 0.11, Paradox of control F $(1,44)$ = 5,16, p = 0.03, ε^2 = 0.11, Feedback F $(1,44)$ =4.43, p = 0.04, ε^2 = 0.10, action- awareness merging, F $(1,44)$ = 5.21, p =0.03, ε^2 = 0.11 transformation of time F $(1, 44)$ = 5.02, p =0.03, ε^2 = 0.11 and loss of self- consciousness F $(1, 44)$ = 4.23, p = 0.05, ε^2 = 0.09. The remaining variables did not elicit a significant difference between exercise groups (see Table 5.1 10).

Mixed ANOVA results showed that over time challenge skill balance (CB) improved over time F $(1, 44)$ = 4.02, p = 0.05, ε^2 = 0.09, and loss of self- consciousness (LS) also improved over time F $(1, 44)$ = 5.89, p= 0.02, ε^2 = 0.12. All of the remaining flow variables did not elicit any significant changes occurring over time. No significant interaction effects were found between time*exercise for any of the flow variables. It should be noted that all flow variables mean and (SD) where higher in the Kinect™ group compared to the mirror-matched exercise group, indicating a higher state of overall flow state during the exercise intervention, both at pre and post testing.

Table 5.1 9: Descriptive statistics (Mean ± SD) for Flow State

| Variable | Pre-Programme | | Post-Programme | |
	XBOX Kinect ™	Mirror-Matched	XBOX Kinect ™	Mirror-Matched
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Autotelic Experience	3.82 (0.69)	3.36 (0.60)	4.00 (0.910	3.40 (0.55)
Clear Goals	3.87 (0.48)	3.55 (0.53)	4.03 (0.62)	3.56 (0.530
Challenge- Skill Balance	4.14 (0.68)	3.69 (0.58)	4.39 (0.69)	3.83 (0.60)
Concentration of Task	3.75 (0.64)	3.11 (0.70)	3.86 (0.82)	3.10 (0.42)
Paradox of Control	4.03 (0.79)	3.70 (0.62)	4.04 (0.59)	3.61 (0.72)
Unambiguous Feedback	3.83 (0.63)	3.44 (0.65)	4.12 (0.66)	3.53 (0.71)
Action- Awareness Merging	3.70 (0.610	3.43 (0.61)	4.02 (0.77)	3.47 (0.52)
Transformation of Time	3.61 (0.660	2.99 (0.70)	3.91 (0.89)	3.00 (0.84)
Loss of Self- Consciousness	3.97 (0.78)	3.37 (0.60)	4.21 (0.63)	3.65 (0.51)

Table 5.1 10**:** Within-group change over time mean differences (95% CI) and adjusted post – intervention between group difference (ANCOVA) for flow state scale

	Within-group change over time (Mixed ANOVA)		ANCOVA
			Adjusted post-intervention difference between groups
	XBOX Kinect™	**Mirror-Matched**	**XBOX Kinect™- Mirror-Matched**
	Mean diff (95% CI)	Mean diff (95% CI)	Mean diff (95% CI)
Autotelic Experience	-0.18 (-0.46 to 0.09)	-0.05 (-0.42 to 0.33)	0.35 (-0.09 to 0.79)
Clear Goals	-0.16 (-0.36 to 0.03)	-0.12 (-0.35 to 0.33)	0.34 (-0.01 to 0.69)
Challenge- Skill Balance	-0.25 (-0.44 to -0.57)*	-0.14 (-0.51 to 0.23)	0.33 (-0.04 to 0.70)
Concentration of Task	-0.11 (-0.34 to 0.11)	-0.00 (-0.36 to 0.36)	0.45 (0.05 to 0.85)*
Paradox of Control	-0.21 (-0.53 to 0.120	0.07 (-0.35 to 0.31)	0.52 (0.10 to 0.94)*
Unambiguous Feedback	-0.23 (-0.46 to -0.00)	-0.11 (-0.52 to 0.31)	0.33 (-0.06 to 0.73)
Action- Awareness Merging	-0.33 (-0.54 to -0.11)	-0.05 (-0.45 to 0.35)	0.44 (0.05 to 0.82)*
Transformation of Time	-0.30 (-0.55 to 0.06)	-0.01 (-0.51 to 0.49)	0.60 (0.06 to 1.14)*
Loss of Self- Consciousness	-0.22 (-0.50 to 0.50)*	-0.32 (-0.07 to 0.70)	0.38 (0.007 to 0.75)*

*** Significant at the *p* < 0.05 level; **Significant at the *p* < 0.01 level; as reported from log-transformed data

5.19 <u>Postural sway differences between groups and over time</u>

Table 5.1 11 shows mean ± SD values for unipedal postural sway for young healthy adults, the mean results show that for all of the postural sway measures (AP SD, AP range, ML SD, ML range and CoP velocity) the exergaming group (Kinect) had a reduction in postural sway and the traditional exercise group also had a reduction in postural sway in four out of the five measures (AP range, ML SD, ML range and CoP velocity) with AP SD increasing over time.

Table 5.1 12 shows the results from the analysis of covariance (ANCOVA) and Mixed ANOVA for unipedal balance with baseline values acting as the covariate showing differences between groups (ANCOVA) and within group changes over time following a mixed analysis of variance ANOVA.

The results show that the only statistically significant difference occurred between exercise groups for ML range. The Kinect™ group showed a significantly lower mean value for ML range compared to the mirror-matched exercise group F (1, 42) =8.63, p = 0.005, ε^2 = 0.17. ML SD almost reached statistical significance (0.09), with zero difference was close to the lower limit of the 95% confidence intervals which would favour the Kinect™ group. Relative to the mirror-matched exercise the Kinect group had a decrease in ML SD by 3.76% which would tentatively suggest improvements in ML SD in the Kinect™ group compared to mirror-matched exercise. 95 % CI's for the other sway variables showed less conclusive with none of them close to zero for either lower of upper limit.

For the results over time the mixed ANOVA showed statistically significant differences occurring for ML SD F (1,44) = 5.77, p = 0.02, $\varepsilon2$ = 0.12, ML Range F (1, 44) = 6.15, p = 0.02, $\varepsilon2$ = 0.13 and CoP velocity, F (1,44) = 10.47, p =0.002, $\varepsilon2$ = 0.20 all in favour of the XBOX Kinect™, by showing larger reductions in postural control. A significant interaction effect for time*exercise was found for ML SD F (1.44) =4.62, p=0.04, $\varepsilon2$ = 0.10 in favour of the Kinect exercise group, as mean± 1SD values for ML SD decreased more 6.12

(1.52)mm to 5.33 (1.14)mm compared to the **mirror-matched exercise** 5.55 (1.40)mm to 5.51 (0.78). As well as ML Range F (1.44) =4.75, p=0.04, $\varepsilon 2 = 0.10$ also in favour of the Kinect exercise group with a larger reduction in ML range over time 33.67 (9.11)mm to 28.23 (5.74)mm compared to the **mirror-matched exercise** 31.85 (10.02) mm to 31.48 (4.44)mm. No other significance was established for any of the other postural sway variables.

Table 5.1 11: Mean ± SD for postural sway during unipedal balance for young healthy adults

		Pre-Programme		Post-Programme	
		XBOX™	Mirror-Matched	XBOX™	Mirror-Matched
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Unipedal	AP SD	8.31 (1.44)	7.62 (1.23)	8.27 (1.92)	8.06 (1.45)
	AP Range	45.11 (8.91)	40.83 (7.10)	42.37 (9.50)	41.55 (6.99)
	ML SD	6.12 (1.52)	5.55 (1.40)	5.33 (1.19)	5.51 (0.78)
	ML Range	33.73 (9.06)	31.85 (10.02)	28.31 (5.71)	31.48 (4.44)
	COP Velocity	55.51 (10.04)	49.64 (10.38)	48.70 (6.96)	46.96 (8.89)

Table 5.1 12: Within group difference over time and between group differences (ANCOVA) for young healthy adults.

		Within-group change over time (Mixed ANOVA)		ANOVA Adjusted post-intervention difference between groups
		XBOX Kinect™	Mirror-Matched	XBOX Kinect™- Mirror-Matched
Unipedal	**AP SD**	0.50 (-0.62 to 0.72)	-0.45 (-1.24 to 0.34)	-0.20 (-1.12 to 0.78)
	AP Range	2.74 (-0.39 to 5.86)	0.72 (-4.30 to 2.85)	-1.77 (-6.13 to 2.59)
	ML SD	0.79 (0.36 to 1.22)*	0.04 (-0.55 to 0.63)	-0.42 (-0.93 to 0.80)
	ML Range	5.44 (2.78 to 8.10)*	0.37 (-3.78 to 4.52)	-3.83 (-6.41 to -1.23)**
	COP Velocity	6.81 (1.93 to 11.70)**	2.67 (-0.78 to 6.13)	-0.32 (-4.88 to 4.24)

* Significant at the *p* < 0.05 level; ******Significant at the *p* < 0.01 level.

5.20 Heart Rate (HR) and Rate of Perceived Exertion (RPE) analysis

5.20.1   Heart Rate and rate of perceived exertion (RPE) between exercise groups.

Heart rate offers an objective measure of physical exertion throughout exercise activity and is vastly used in the field of sports and rehabilitation to gain levels of performance. HR is easily measured by wearing a HR monitor around the chest at skin level and wearing a watch which picks up the HR output.

Rate of Perceived Exertion (RPE, Borg 1985) is a subjective scale of physical exertion and is used as a psychometric scale of how the participant rates their own physical exertion. RPE is used frequently in sports and physiology, especially when performing maximal tests such as VO2max or lactate threshold testing. RPE is rated on a scale of 6 (very very light) to 20 (very very hard).

Table 5.1 13 shows results for baseline and post-test HR and RPE data respectively for both exercise groups. Throughout the testing, both exercise groups (Kinect™ and standard) all participants wore a polar heart rate monitor and rated their perceived exertion after every activity. The average HR and RPE were taken from each session and compared from baseline (week 1) to end of the exercise session (week 4).

Table 5.1 14 shows ANCOVA results for between exercise group difference, with HR and RPE at baseline acting as the covariates and within group difference over time.   No statistical difference occurred between groups for HR but statistical significance was apparent between groups for RPE $F (1, 44) = 12.30$, $p = 0.001$, ε^2 0.23. The XBOX™ group perceived lower levels of physical exertion, according to the RPE scale compared to the mirror-matched exercise group, this was an interesting point as the mean HR was higher in the Kinect™ group compared to the mirror matched gym based exercise with no virtual stimuli , this may suggest that although the physiological response was greater in the Kinect group, they actually perceived less of an exertion due to the immersion into the activity and enjoying the work out.

Within- differences occurring over time following a mixed ANOVA results showed that over time there was a significant difference F (1,44) = 126.97, p = 0.000, ε^2 = 0.75 for HR in both exercise groups (Kinect and standard) this would be expected due to increase in duration and intensity of the exercise and therefore elicit physiological responses to exercise intensity. The same also occurred in relation to RPE that over time this significantly increased F (1, 44) = 452.9, p = 0.000, ε^2 = 0.91 in both exercise groups. Both exercise groups showed significant increase in both HR and RPE showing that the exergame was eliciting similar physiological response as standard matched exercise.

Table 5.1 13: Baseline and post-test unadjusted HR and RPE mean ± SD

	HR	HR	RPE	RPE
	Kinect™	Mirror-Matched	Kinect	Mirror-Matched
Week1	117.56 (17.5)	115.85 (21.85)	9.56 (2.04)	9.29 (1.38)
Week 2	130.30 (18.73)	124.00 (7.49)	11.61 (1.85)	11.43 (1.28)
Week 3	144.00 (10.20)	134.57 (10.97)	12.08 (1.59)	12.43 (1.21)
Week 4	150.21 (13.70)	149.57 (6.46)	13.39 (1.44)	14.29 (0.90)

Table 5.1 14: Within group differences over time (mixed ANOVA) and between group differences (ANCOVA) with 95% CI for HR and RPE data for healthy young adults.

	Within-group change over time (Mixed ANOVA)		Adjusted post-intervention difference between groups (ANCOVA)
	XBOX™	Mirror-Matched	XBOX™ - Mirror-Matched
	Mean (95% CI) diff	Mean (95% CI) diff	Mean (SE, 95% CI) diff
HR	-32.65 (-39.79 to -25.51)***	-33.71 (-43.89 to -25.59)***	0.37 (-6.05 to 6.79)
RPE	-3.83 (-4.46 to -3.20)***	-5.00 (-5.58 to -4.42)***	-1.01 (-1.60 to -0.45)***

* Significant $p < 0.05$ level; **Significant $p < 0.01$ level; *** Significant $p < 0.001$ level

5.20.2 Summary

Overall the effects of exergaming training using the Kinect™ compared to mirror-matched exercise showed improvements in acceptance, flow and balance.

In relation to psychological variables, the levels of technology acceptance where higher in all variables of UTAUT for the Kinect™ group compared to the mirror-matched exercise with performance expectancy, social influences and behavioural intention all showing a statistically significant difference between the exercise groups in favour of the exergaming group ($p<0.05$). Significant differences over time were established in PE and EE ($p<0.05$), and when an interaction of time* exercise was performed SI and BI showed statistical significance, all in favour of the exergaming group compared to the mirror-matched exercise. Multiple regression analysis also showed that overall when covariates were grouped together (PE, EE, SI, age and gender) that the model accounted for 47% at pre exercise and 71% post exercise in predicating behavioural intention. At pre exercise PE and EE were significant predictors of behavioural intention and PE and SI were significant predictors of behavioural intention post exercise.

Flow state scale showed significant differences occurring between the exercise groups, for concentration of task, paradox of control, unambiguous feedback, Action Awareness Merging, transformation of time and loss of self- consciousness with a higher score occurring in the exergaming group. The results over time showed a statistically significant improvement for challenge skill balance, and loss of self- consciousness in again, favour of the exergaming group. No interaction effect were established between time x exercise.

The results for balance showed that there was a significant improvement (reduction in sway) in ML range for the Kinect™ group compared to the mirror-matched exercise, with ML SD almost reaching statistical significance. Over time (4 week intervention) ML SD, ML range and CoP improved over time with greater levels of improvement occurring in the Kinect™ group.

The results from the HR and RPE analysis show interesting results. Over the duration of the 4 week training protocol, HR did increase over time which would be expected during a ramp protocol training. However, despite their being no statistical significance occurring between the exercise groups in terms of mean HR, the Kinect™ group did show a higher average HR, yet a statistically significantly lower RPE. This would indicate that despite the high physiological exertion, participants still rates the activity on average as moderately intense exercise, despite high HR. This offers some explanation in relation to the flow questionnaires that due to the higher levels of immersion into the exergaming could have had a potential effect on lower levels of RPE as a result of enjoyment of the activity, and being actively immersed into the activity.

This chapter shows the potential for exergaming as a means of exercise for balance training, levels of intention and flow were significantly higher in the exergaming group compared to the mirror-matched exercise in healthy active adults. Interestingly, regarding biometric intensity (HR/RPE) heart rate levels on average were higher in the exergaming group rather than the mirror-matched exercise group. Lower levels of RPE in the exergaming group compared to the mirror-matched exercise would suggest that people are more immersed into the activity so that they rate their exertion levels lower, due to the fact they are enjoying the activity and feel immersed into it, rather than the mirror-matched exercise, these results can be supported by the UTUAT and flow findings.

This chapter indicates good reliability between the data between all of the psychological subscales for both UTAUT and flow with high internal alpha consistencies.

5.21 Discussion from the randomised controlled trial of physically active healthy Adult's acceptance (behavioural intention), flow experience (absorption in the activity) and postural control (before and after), exercising in: an exergaming environment (XBOX Kinect™) or mirror-matched exercise

5.22 Introduction

This chapter will discuss the findings from healthy young adults within the context from previous exergaming literature regarding acceptance and immersive nature of exergaming and the second part of the chapter will have emphasis on postural control in a healthy subject population in relation to past literature.

5.23 Unified Theory of Technology acceptance for Healthy young adults during exergaming

The current study showed a statistically significant difference between exercise groups for performance expectancy (PE), social influences (SI), and behavioural intention (BI) all in favour of the exergaming (Kinect™) exercise group. As UTAUT has never been applied to exergaming in the past the results would tentatively suggest that the reasons for this significance occurring between exercise groups could be due to the levels of enjoyment experienced during the exergaming as opposed to conventional gym based exercise with no VR. Brumles et al., (2008) concur with this notion as when they compared two exergaming based games (Wii Fit™ and Dance Dance revolution) to traditional exercise the levels of enjoyment where significantly greater in the exergaming program compared to the traditional exercise. Fitzgerald et al., (2010) also support this notion between exercise groups as when they compared intrinsic motivation between Wii Fit™ exercise and traditional gym based exercise the "interest and enjoyment" category was significantly higher in the exergaming group. Widan McDonald, and Abresch, (2006) state that video gaming is enjoyable and provides motivation to exercise, having the motivation to exercise is essential towards behavioural intention and specifically intrinsic motivation, as the person wants to perform the

exercise without any external gratification. This explanation would offer some degree of plausible explanation as to why performance expectancy (PE), social influences (SI), and behavioural intention (BI) where significantly higher in the exergaming group as opposed to the mirror matched gym based exercise with no virtual stimuli group. A key element within the UTAUT is the aspect of behavioural intention to use the system, as BI was significantly higher within the exergaming group (Kinect™) this demonstrates the plausibility of using the Kinect™ as a method of exercise and the potential to keep using the system in the future for exercise purposes. Descriptive statistics showed that age was significantly different between the exergaming and mirror-matched exercise, a potential consequence of this could be variations in UTAUT which have been noted in previous literature for younger people to have higher levels of PE; however as the exercise groups were randomised through blind card-randomisation this factor could not be controlled for. Additionally in the multiple regression age did not show any significance in predicting behavioural intention. Only PE was a significant predictor of BI at both baseline and post exercise, a possible explanation for this could be due to watching demonstrations of the Kinect™ before actual use and perceiving the benefits of using the Kinect™ as useful to perform exercise. At post exercise only PE and SI were significant predictors of BI. A possible explanation for why social influence may have had a significant effect post exercise could be due to the interaction with the exergame system and the elements of allowing multi- player, however this was not measured during the thesis as only single players were used therefore this can only tentatively be summarised. The use of the Kinect™ as a method of enjoyment could also prompt social interaction and competition, as the subject group where healthy active adults the elements of competition may have been prevalent when rating social interaction. O' Donovan et al., (2012) supported the notion of social interaction in respect to energy expenditure when playing the Kinect and Wii, they showed that when players played mutli-player their energy expenditure increased as opposed to single player. As the subject population in this thesis were young healthy adults, the familiarity with gaming consoles may have had an effect on social influences as research has indicated that 59% of gamers in the UK are aged between

6 and 65 years old which would fit well inside the mean of the current study (33.84 years) with the average age of a gamer estimated at 28 years (Pratchett 2005). The enjoyment of playing games together with peers may offer more enjoyment than playing alone against the computer, this can partly be seen in normal computer gaming and the increase in online gaming as a means of social interaction with other online players instead of against the computer. Weibel *et al.,(*2008) showed that people who played online against another human controlled opponents had greater presence and flow compared to playing against a computer controlled opponent. The reason social influences were only a significant predictor of behavioural intention after use could be due to the actual playing of the game, as it is believed that in order to develop thoughts of using a new system actual experience is needed before any true generalisations can be made in relation to social influences (Davis and Venkatesh 2004). A possible explanation of why social influence showed to be a significant predictor of behavioural intention in study 2 but not in study1 could be that the Kinect is a commercial exergame and people could relate to the Kinect in a home-based environment for leisure and exercise purposes both in single- and multiplayer (with a peer/friend) mode. However, the IREX™ used in study 1 was a purpose built exergaming system which had a 10 foot green screen, therefore in terms of social interaction this may not have been relevant to many participants, especially in terms of playing at home or with someone else due to the space required to play. As UTAUT is novel to exergaming, the findings from the current study are novel and address an important gap in current literature in relation to behavioural intention to use exergaming systems for future exercise.

5.24 Flow state scale for Healthy young adults during exergaming

The results from the flow state scale questionnaire (Jackson and Marsh, 1996) showed that on a whole the exergaming group (Kinect™) showed higher mean scores throughout the exercise intervention from baseline to post testing, all of the participants in the exergaming group rated the 9 subscales higher than in the mirror matched gym based exercise with no virtual stimuli group. Following statistical analysis it was evident that there the exergaming

groups showed significant differences in, concentration of task, paradox of control, unambiguous feedback, action-awareness merging, transformation of time and loss of self-consciousness. The significance favoured the exergaming group as scores where closer to 5 (meaning strongly agree on the likert scale). Possible reasons to explain this significance can be accounted for in the immersive nature of the exergaming equipment over mirror-matched exercise. The unambiguous feedback especially could have shown potentially higher results due to the automatic feedback on the exergaming equipment, as once the participants complete the games they are scored on a system of bronze, silver and gold medals and also points achieved, this gives the participants the opportunity to analyse their own performance and gives them the opportunity to improve if their skills match the levels on the games.

Table 5.1 15 shows the comparison in results of flow in relation to exergaming. Our results can be directly compare to two exergaming and flow research papers (Thin et al., 2011; Limperos et al., (2011) regarding the difference between exercise groups this can be compared to Limperos et al., (2011) as Thin et al., (2011) only compared differences in flow over time. Limperos et al., (2011) compared the differences in flow and enjoyment between the Nintendo Wii™ and the Play Station™ 2 when playing Madden football game. The results showed than enjoyment and control were significantly greater in the PS2 compared to the Wii™. Our current study partly support this notion as there were significant differences between control in our current study between the exercise groups in favour of the Kinect™. Despite the Kinect™ being a new games console the participants in the groups perceived greater levels of control, this could be due to a learning effect over the 4 week period and increase in winning of the games during the Kinect™ as opposed to traditional exercise. Despite Limperos et al., (2011) showing differences in enjoyment and flow, direct comparisons made to our current study are difficult due to a number of methodological differences, for instance our study compared the differences between two methods of exercise, whereas Limperos et al., (2011) compared traditional gaming (PS2) against

exergaming (Wii™), another issue is the difference is session times, as our results are after a 4 week training period comprising o 12 sessions, whereas Limperos et al., (2011) was only one single session, with variations in game play.

In respect to differences over time our results concur with Thin et al., (2011) in that over time there was significant improvement for challenge-skill balance and loss of self-consciousness for exergaming exercise. Our current results indicate that those in the exergaming group had significantly improved for challenge- skill balance, this partly could be due to the increase in activity levels and achieving higher scores over the duration of the four week period, as the games were neither too easy or too hard which allowed a good challenge- skill balance and effectively higher perceptions of this in relation to flow. For loss of self- consciousness this is related to the level of immersion into the exergame, as with the Kinect™ the participants act as the controller and effectively their body movements control the game, so the levels of concentration to be successful in the game are usually high. Concurring with Thin et al., (2011) when playing exergames the players "gaze" is usually focused directly on the screen as opposed to traditional based exercise when the participants focus may be else were. This could tentatively explain why loss of self- consciousness was significantly higher in both the current study and Thin et al., (2011). Although Thin et al., (2011) measured all 9 dimension of flow and effectively is the only study that can be directly compared to our current results; a methodological issue with the results in Thin et al., (2011) are that the flow state was collected including exergaming exercise, and normal cycling exercises together; this appears an obvious source of error in relation to applying flow to exergaming, as the results can only be partly related to exergaming as traditional methods of exercise were also included within the measure of flow. The findings from the current study are novel and address an important gap in current literature in relation to applying flow directly to exergaming either comparing exergaming to other forms of exercise or analysing flow with exergaming alone.

Table 5.1 15: Outcome measures for Flow

	Participants	Flow measures	Results
Current Study	Healthy young adults	Flow state scale Jackson and Marsh (1996)	Improvements between groups in clear goals, concentration of task, paradox of control, unambiguous feedback, action-awareness merging, transformation of time and loss of self- consciousness. Over time significant improvements Challenge-Skill Balance and Loss of self-consciousness.
Thin et al., (2011)	Healthy Young Adults	FSS-2	Improvements over time for total flow for Challenge-Skill Balance and Action–Awareness Merging and Loss of self-consciousness.
Limperos et al., (2011)	Healthy Young Adults	Adapted flow from Jackson and Marsh (1996)	People playing traditional gaming (play station) significantly greater levels of enjoyment and flow (sense of control) over playing the Wii
Sinclair et al., (2012)	Healthy Young Adults	Duel Flow	No statistical differences, nor where the participants "immersed" in the game.
Lai et al., (2012)	Healthy Young Adults	74-item EFSQ (exergaming flow scale)	More frequently and longer time durations for playing exergaming may increase the time spent in flow and also increase enjoyment.

5.25 Postural sway in Healthy adults

The current study showed that there was significant post-test difference in medio-lateral CoP excursion in unipedal standing between the exercise groups after the intervention, with lower values in the exergaming group, indicating better postural stability. There was no other significance occurring between the exercise groups for the remaining sway measures (AP SD, AP range, ML SD and CoP). Over time, there was a significant post-test difference occurring in ML SD and ML range, and CoP velocity. Again this significance was established in the exergaming group, indicating the potential for balance training using an exergaming method over mirror-matched exercise.

Table 5.1 16 shows the results of from the current study compared to measures of unipedal standing under similar test conditions for exergaming and postural control research from two other studies (Brumles et al., 2008; Vernadikis et al., 2012) comparisons were only made if unipedal balance was assessed, out of the two papers one of them only collected data from a force plate which can be directly compared to the current study (Brumles et al., 2008). As Vernadikis et al., (2012) assessed force through the biodex balance machine, another reason why this was not directly compared to the current study, was that during the assessment of postural control the plate was unstable and moved up to 20 degrees.

The findings from healthy young adults indicate that playing exergames (Kinect™) compared to mirror-matched exercise significantly improves balance in the medio- lateral direction. A possible explanation for the improvement in the medial- lateral direction in study 2 could be due to the majority of movements occurred in the frontal plane of motion requiring fast side to side movements. This is particularly useful in respect to balance interventions, although there is limited research in respect to exergaming and postural control, the results can tentatively be supported from those of Brumels et al., (2008) who also found significant improvements occurring between exercise groups for force plate measures. The results from Brumels et al., (2008) showed significant improvements for both DDR and the Nintendo Wii

groups compared to traditional exercise in the AP direction. A possible explanation for the reasons why the current results showed significant improvements in ML direction and Brumels et al., (2008) showed significant improvements in the AP direction could be due to the different exergaming systems used. As during the Kinect the majority of movements occurred in the frontal plane of motion requiring fast side to side movements, which may explain the improvement in the ML direction. Collectively, the results from the current study and Brumels et al., (2008) show significant improvements over time which could indicate the beneficial effects of a 4 week exercise training program to improve balance in healthy active adults. Although similarities appear in the results, it is worth noting the differences in methodological testing of postural control, which may have an effect on the interpretation of the results. During the assessment of postural control in Brumels et al., (2008) they only assessed postural control using one repetition of 10 seconds. Having only one repetition could lead to errors occurring in the results, as for example if a subject had a large sway occurring in the group this could bring the mean scores up and may not be truly representative of mean scores, as no baseline or post test data were available in the review it is hard to determine the true effect of only using one trial. Although one trial has been used previously in literature to assess postural control (Le Clair and Riach 1996), Ruhe et al., (2010) recently conducted a systematic review of test- re test reliability of postural control and indicated that on average 3-5 trials are deemed acceptable for the assessment of postural control. Using short test duration of 10 seconds is also a methodological issue with Brumels et al., (2008) study as in a study assessing optimal duration times for postural control (Le Clair and Riach 1996) 10s trials showed to be the least reliable of all of the time durations.

Table 5.1 16: Comparison of studies regarding exergaming and postural control in healthy young adults

Study	Age (mean ± SD)	Participants	Group	Intervention	Exergame	Force plate tests	Results
Current study	33.96 ± 12.6	Healthy active adults 27 (M) 20 (F)	Exergame Mirror matched gym based exercise with no virtual stimuli.	3 x 4 weeks	XBOX Kinect	Kistler force plate 5 x 30 sec unipedal AP SD, AP range ML SD ML Range CoP velocity.	Sig reduction in ML range between groups. Sig reduction ML Range, MLSD and Cop Velocity over time.
Brumels et al., (2008)	19.56 ± 1.69	Healthy active adults 12 (M) 13 (F)	Wii, DDR, balance and control	3 x 4 weeks	Nintendo Wii™ and DDR™	AMTI AccuSway force plate 1 x 10 sec unipedal eyes open/ eyes closed AP, ML, CoP	Sig reduction between groups AP and CoP for DDR over traditional and CoP in AP direction for DDR and Wii compared to trad. Sig reduction in ML and CoP for DDR over time. Sig reduction for CoP Wii group over time.
Vernadakis et al., (2012)	20.56 ± 0.52	Healthy active adults 18 (M) 14 (F)	Nintendo Wii Standard balance exercise	2 x 8 weeks	Nintendo Wii™	Biodex Balance 3 x 20 second unipedal dominant and non-dominant leg. API and ML I	Sig reduction in AP and ML overtime but not between groups.

5.26 HR and PRE during exergaming compared to mirror matched gym based exercise with no virtual stimuli

Heart rate (HR) and RPE have been commonly used in past research as a valid indication on physical exertion during exercise (Coquart et al., 2009; Dunbar et al., 1992; Foster et al., 2001; López-Miñarro & Rodríguez 2010). The HR data from study 2 showed there was no significant post-test difference between exercise types (exergaming and mirror- matched exercise), as both groups reached moderately intense exercise at an estimated 82% of maximum heart rate (200-age). This shows that exergaming can elicit similar physical cost of exercising compared to mirror-matched exercise. In relation to making true generalisations regarding the Kinect further work would need to be conducted in a range of sporting activities and a more in depth physiological assessment would assist in this such as using breath by breath analysis. The results from the rate of perceived exertion (RPE) showed some interesting statistical would indicate that despite high physiological response to exergaming, participants perceived this as relatively low in terms of physical exertion. These results indicate that the level of immersion into the exergaming could influence the RPE scores. As results from the flow state scale questionnaire shows that participants in the exergmaing group have higher levels of immersion into the activity. A wide range of literature has reported increased energy expenditure during exergaming (Graves et al., 2007; Lanningham- Foster et al., 2009; *Bosch* et al., 2012), through increase HR and metabolic rates, yet there is limited information regarding RPE and exergaming.

One report that has compared the two is Sell et al., (2008) who compared HR and RPE in male college athletes who were inexperienced and experienced at playing exergames Dance dance revolution (DDR), the results showed that in the experienced players HR was significantly higher 161.2 ± (13.8) compared to the inexperienced players 95.5 ± (10.5) with the same occurring for PRE 13.4 (1.5) compared to 10.7 (1.7). The results from this study provide interesting comparisons to the results from the current study in relation to HR and

RPE as in the current thesis HR values reached 150.09 ± (2.20) with RPE at 13.33 ± (0.20), these results shows very similar in relation to the perceived exertion of Sell et al., (2008). Although the comparisons can be made that relatively high HR can produced moderate levels of perceived exertion (current study and Sell et al., 2008) it should be noted that in the current study both male and females were used as opposed to males only in Sell et al., (2008). Tentatively the results would suggest that due to the immersive nature of the exergames compared to mirror-matched exercise that people can physiologically achieve moderate to high HR during 30 minutes of exergaming which would be in accordance with ACSM daily exercise guidelines, and RPE levels are relatively moderate at "somewhat hard".

6.   CHAPTER 6: GENERAL DISCUSSION AND CONCLUSION

6.1   Introduction

This thesis has generated new knowledge regarding the effect of exergaming compared to mirror-matched exercise on levels of technology acceptance (behavioural intention), flow and postural control in healthy non-active and active young adults. Levels of technology acceptance, and flow were observed to be predominantly higher in the exergaming group, with reduction in postural sway measures occurring for both within and between groups for both studies. This chapter synthesises these findings and discusses the limitations of the thesis and potential directions for future research to better understand the effects of exergaming compared to mirror-matched exercise on technology acceptance, flow and postural sway.

6.2   Aims of the thesis

This thesis was concerned with exploring whether exergaming training can have an effect on levels of acceptance, flow and postural control compared to mirror-matched exercise in young healthy non-active and young healthy active adults. The thesis had four primary aims developed from the initial research question:

1) To compare participants' acceptance (behavioural intention) and flow experience (absorption in the activity) between exercising using an exergaming environment versus mirror-matched exercise.

2) To compare the effects of exergaming based training versus mirror-matched exercise on postural control.

3) To compare the biometric intensity of exergaming versus mirror-matched exercise (Heart rate and rate of perceived exertion).

4) To explore the relative contribution of components of the unified theory of technology acceptance and use of technology (UTAUT) on behavioural intention.

In Chapter 2 of this thesis, the literature reviews highlighted that exergaming was in the infancy stage of development with regards to technology acceptance (behavioural intention), flow and postural control in healthy young adults. The psychological literature identified a significant lack of evidence regarding flow and exergaming with only four papers were found between 2010-2012 (Sinclair et al., 2010; Limperos et al., 2011; Thin et al., 2011; Lai et al., 2012) with only two of the studies analysed the whole 9 subscales which make up flow, with variations between a 36 item scale (Thin et al., 2011) and an extended version of flow with 74 items (Lai et al., 2012). To date, no previous literature had explored the effects of UTAUT to exergaming to analyse the behavioural intention to use exergaming, therefore the thesis aimed to bridge the gap of knowledge in this area. By investigating the effects of technology acceptance and flow during exergaming compared to mirror-matched exercise, this thesis allowed the exploration of a true comparison of exergaming compared to the same mode of exercise (excluding the virtual stimuli). To date, previous studies have analysed the effects of flow when using a game bike (bike with a virtual monitor attached in front), (Sinclair et al., 2010), exergaming combined with cycling and compared against published norms for exercise activity and dance flow states (Thin et al., 2011), exergaming verse normal sedentary gaming (Limperos et al., 2011), and recall experiences of exergaming (Nintendo Wii, Kinect, Play Station move), (Lai et al., 2012). By investigation flow and UTAUT during exergaming compared to mirror matched gym based exercise with no virtual stimuli, this thesis had the scope to determine whether exergaming can elicit states of flow and have an effect on behavioural intention to use exergames as a mode of exercise compared to that with no virtual stimuli. In relation to the UTAUT model the thesis analysed the relative contribution of components of the unified theory of technology acceptance and use of technology (UTAUT) on behavioural intention. In essence it specifically focused on elements of the UTAUT model that could predict future intention.

Regarding the potential physiological benefits that exergaming may offer, the thesis explored the effects of exergaming versus mirror-matched exercise on postural control. The literature

review identified a significant lack of evidence relating to the effects of exergaming on postural control as only three studies had analysed the effects of postural control using exergaming compared to other methods of exercise in young healthy adults Brumels et al., 2008; Fitzgerald et al., 2010; and Vernadakis et al., 2012). One aspect that remained unclear was whether exergaming compared to mirror-matched exercise would have an effect of postural control as the previous literature revealed bias towards outcome measures and exercise intervention such as Brumels et al., (2008) had a control group practice the Star Excursion Balance Test, which was one of the outcome measures in the investigation. Therefore the current thesis investigated whether exergaming compared to mirror matched exercise with no virtual stimuli had an effect on postural control. The use of mirror matched exercise was a novel aspect to the thesis as this had, to the author's knowledge, not been previously analysed before and the results would add to the gaps in literature regarding the effects of exergaming on postural control. The literature also indicated the physiological effects of exergaming compared to traditional exercise, the thesis specifically looked at the biometric intensity in exergaming compared to mirror matched exercise, to analyse the physiological effects of exergaming and whether it can elicit moderate levels of physical exertion, as measured by mean heart rate and RPE.

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

1) The effect of exergaming compared to mirror-matched exercise on technology acceptance (behavioural intention) and flow.

2) The effect of exergaming on postural sway parameters during quiet standing in healthy non- active and healthy active adults.

6.3 Synthesis of findings

Four major findings emerged from the thesis. Firstly, levels of technology acceptance were significantly higher during exergaming compared to mirror matched exercise, this was specifically the case for performance expectancy (PE), as PE was a significant predictor of behavioural intention. Secondly, levels of flow were greater in favour of the exergaming, over a four week exercise programme. Thirdly, postural sway as measured by a force plate was significantly reduced following exergaming interventions compared to mirror matched exercise. Fourthly, biometric intensities did not show any statistical difference for mean heart rate (HR) between exercise groups, indicating moderate to high levels of physical activity, whereas subjective rate of perceived exertion (RPE) was significantly lower in the exergaming group. A possible reason why participants in the exergaming groups showed significantly lower levels of RPE could be partially related to the flow results in respect to participants were more immersed into the gaming environment and the games acted as a distraction from the physiological effects of the exercise during exergaming. As this relationship between RPE and flow were not directly measured against each other this can only be speculated as a possible explanation for lower levels of RPE.

6.3.1 Unified Theory of Technology acceptance and use (UTAUT)

Living in a western society there is a continuum in the development of new technologies and devices, whether it is from personal computer (PC) desktops to notebooks and I Pads, or from traditional sedentary gaming to exergaming, Davis (1993) believes that is essential to understand user acceptance for the success or failure of a new information system. Despite the range of success exergaming has had in commercial market and rehabilitation setting, no research has looked at levels of technology acceptance and largely why or if people would continue to use exergames once the novelty had worn off. The current thesis, applied a technology acceptance model (UTAUT) to exergaming to help bridge this gap in literature.

The research reported in this thesis indicates that young healthy adults (non- active and active) have significantly higher levels of performance expectancy (belief that the exergaming system will help them achieve exercise goals) compared to mirror matched gym based exercise with no virtual stimuli. This research has extended the UTAUT to the domain of exergaming by demonstrating that performance expectancy is a predictor of behavioural intention. In both studies, performance expectancy significantly predicted behavioural intention at both pre and post exercise intervention. Performance expectancy was also significantly higher in the exergaming groups in both studies (non – active and active adults). In study 1 (non-active) adults, effort expectancy was also a significant predictor of behavioural intention post exercise. Effort expectancy relates to the ease of use of the equipment, interestingly the exergaming system (IREX™) was perceived easy to use a possible explanation for this could be due to the simplicity of the movements needed during the gaming, and a virtual demonstration before the game. Previous technology acceptance literature has suggested that effort expectancy (ease of use) is a strong predictor of behavioural intention (Davis 1989; Gentry and Calantone, 2002; Venkatesh et al., 2003; Vijayasarathy, 2004). Research has also indicated the females intention to use a system is more strongly related to ease of use (Ong & Lai, 2006). However, multiple regression analysis did not find any significant differences between gender in the thesis.

In healthy active adults (study 2) social influences were also a significant predictor of intention at the end of the exercise programme. This finding is particularly useful in that people would socially play exergames as a means of exercise with their social peers. Using commercial exergaming could have had an effect on social influences, as people could relate to using the Kinect in their home; however, this is speculative as no analysis was done regarding home exercise.

Overall when direct effects (PE, EE, SI age, gender) were regressed on BI, they produced a significant effect at all-time points with R^2 values ranging from 35-46% in study 1 and 47-

71% in study 2. With the longer duration of exercise producing the greatest level effect 71%, which is similar to Venkatesh et al., (2003) who found that when direct effects were regressed they were responsible for prediction 70% variance in BI.

The results indicate that performance expectancy is the strongest predictor of intention in respect to relative contribution of components of the unified theory of technology acceptance and use of technology (UTAUT) on behavioural intention. The application of the UTAUT offers a novel insight into levels of acceptance using exergaming and the potential effect it may have on levels of exercise acceptance.

6.3.2 Flow Experience

Gaining a sense of reward from performance has been linked to motivation and factors which may result in performance being repeated. The results from the flow questionnaire showed opposite effects occurring between healthy non- active (study 1) and healthy active adults (study 2). In the first study, there was no significant difference between exercise groups occurring, the only significant differences occurred over time for autotelic experience (AE), clear goals (CG) and transformation of time (TT) in favour of the mirror-matched exercise group. A time x interaction (exercise) effect was also established for paradox of control (PC). Whereas in study 2 the exergaming group had significantly higher levels of flow in 6 of the 9 flow subscales; concentration of task, paradox of control, unambiguous feedback, action-awareness merging, transformation of time and loss of self- consciousness. Over time challenge skill balance and loss of self- consciousness were also significantly different for the Kinect exercise group, showing elevated levels of flow post exercise. Possible explanations for reasons for difference could be that in study 1, participants were unfamiliar with the exercise system, and may have had to actively think about the movements and having a new interface (IREX™) may have taken participants longer to get used to, especially given the short duration of the intervention. Limperos et al., (2011) had similar results in that when comparing the Nintendo Wii against the Play Station 2,

participants had greater levels of enjoyment and flow during the PS2 as they were more used to the interface.

The increase in flow in study 2, could be speculated to be due to two possible reasons 1); a longer duration of the exergaming (4 weeks) compared to study 1 meant that participants were used to the gaming environment by the end of testing and 2); as the subjects population was healthy active adults, they would already be familiar with normal exercise with no virtual stimuli, and the inclusions of a virtual game (Kinect™) may have elicited a new challenge for them.

The results provide novel findings in that the two models of technology acceptance and flow state can be related to analyse people's motivation and intention to use new equipment in the future, however, more research needs to be done in order for this generalisation to occur.

6.3.3 **Postural Sway**

The use of exergaming for healthy adults showed significant differences between exercise groups in favour of the exergaming group for both healthy non-active and healthy active young adults. The results from the non-active adults showed that AP SD and AP range significantly improved in the exergaming group compared to the mirror-matched exercise and results from the second study (healthy active adults) showed that ML range significantly improved in the exergaming group, with significant difference over time for ML SD, ML range and CoP velocity.

This thesis points to the importance of exergaming training for enhancing balance in healthy non active and active young adults. The differences in significance in sway parameters between AP directions (AP SD & AP range) compared to ML (ML SD, ML range) and CoP velocity could be explained in the difference in movement patterns during the different exergaming systems. In the IREX™ system the majority of the movement occurred in the

sagittal plane of movement (forward and backward) stepping, whereas in study 2 (Kinect) the movements incorporated a substantial amount of medial lateral (side to side) movement in the frontal plate, as well as jumping and squatting down. As study 2 used a commercial exergame, the movements and the interactions of the games tend to be relatively fast, which may have had an effect on overall CoP velocity, as during the exergaming games required quick reaction times.

A possible explanation for why the exergaming group showed significant improvement in postural sway compared to mirror-matched exercise could be due to the visual stimulus used in the exergaming protocols. Whilst playing the exergames people adjusted their posture in standing in response to movement in the visual surround. For example participants had to react quickly to a visual stimulus on the screen in the exergaming exercise when for example dodging a barrier my moving the body laterally, which may in turn, had a positive effect on their postural control post exercise. The effects of movement in the visual surround are dependent on the degree and nature of the movements, and the relative effects of permutations of the different factors are not known (Horlings et al., 2009). Sensory reweighing may have occurred during the exergaming training which caused a reduction in sway, in particular those in the exergame group in both studies may have had altered the amount of sensory input from the three main inputs; somatosensory, vestibular and visual inputs (spatial orientation), which meant that during static standing they were more stable and had better postural orientation. The effects of movement in a visual surround and sensory reweighing while plausible are speculative in the thesis, as it was not directly measured.

The results would tentatively suggest the potential use of exergaming as an enjoyable and immersive exercise modality to improve postural control in healthy active adults, using a 4-week exercise intervention.

6.3.4 Biometric intensity of exercise

The effects of biometric intensity (HR/RPE) on exergaming suggests that exergaming can produce moderate to high intensity exercise in respect to average HR, moderate intensity exercise should elicit hear rate values of 55 to 69% of age predicted maximum heart rate (220 beats per minute – age) and RPE levels between 12 and13 (ACSM, 2009). Although both exercise groups, elicited similar mean HR each week during testing, mean RPE was significantly lower between exercise groups, at post exercise (week 4), showing that the exergaming group perceived the exercise as somewhat hard, whereas the mirror-matched exercise perceived the exercise as hard at week four. This could be due to that when people were exercising in the exergaming group they were more immersed into the activity, (loss of self-consciousness) and the enjoyment factor may have subconsciously outweighed the physiological demands of the exercise.

6.4 <u>Limitations of the research</u>

Firstly the thesis presents a range of strengths of the research:

The thesis provides two robustly designed studies, using rigorous methodologies that provide novel information regarding technology acceptance, flow and postural control during exergaming compared to mirror-matched exercise, providing important findings which will inform future research, (see Appendix 22).

The current thesis offers a novel application of the UTAUT to exergaming research and in addition, the use of matched exercise with no virtual stimuli was applied in both phases of the PhD. Using a RCT design provides key information for the effects of exergaming on static postural control in healthy young adults, as to date only one previous study has used a RCT design and analysed the effects of dynamic postural control in healthy young adults (Fitzgerald et al., 2010).

Participants were not asked whether they had previous gaming experience to other systems such as the Nintento Wii, Sony Eye Toy, XBOX, PlayStation which may have had a potential implication on the outcome results. This was deemed a limitation to the study, as previous gaming experience could be a confounding factor influencing the outcome variables, especially with regards to intention if they previously and were currently gamers. Although past experience may have had an effect, the thesis was focused on exergaming play, not sedentary game play, and this was controlled for by only including participants with no previous experience of the exergaming systems (IREX™ and XBOX Kinect™) prior to testing. As the IREX™ was a purpose-built rehabilitation system, participants had no experience and the XBOX Kinect™ was only released for commercial sale at the beginning of study 2, thus minimising any potential experience.

The application of the XBUS™ system to measure postural sway during static standing, added a novel aspect to the study, however no significant correlations were found between the system and force plate.

The thesis, offers a new approach to balance training, in that no publications exist with regards to using the XBOX Kinect™ to train balance, this is the first study to the authors knowledge to use the Kinect as an exergaming system for balance training.

Despite contributions to knowledge a number of limitations point to interesting opportunities for future research in the exergaming field of research. During the exercise intervention neither the investigator nor participants were blind to the exercise condition being tested. This procedure would not have been feasible for the current thesis as the investigator needed to be present during the exercise sessions and was the sole researcher. Although the postural sway data provides interesting information regarding static balance, data cannot be related to dynamic balance or functional movement.

The thesis has produced various important findings in relation to the application of exergaming for technology acceptance, flow and postural control that require future investigation. Areas detailed below provide potential development and understanding necessary to enhance exergaming research and development.

6.5   Future Research

6.5.1   Technology acceptance and flow

The results showed that UTAUT and flow can be successfully applied to exergaming research. As UTAUT is new to exergaming, more robust information is needed from a variety of conditions such as children, elderly, and clinical populations to see the true effects of exergaming and behavioural intention. Further studies of flow are also needed to be explored in a range of populations, as at present only healthy adults have been explored. An

addition towards gaining a wider understanding of behavioural intention would be to measure actual usage over a longitudinal period of time for exergaming interventions. Furthermore work is needed to extensively apply UTAUT to the exergaming field, in order to gain a wider understanding of its application in the field.

6.5.2   Balance

The results from the current thesis indicate the beneficial effects of exergaming on improving postural control in unipedal standing in healthy adults. Future work should be carried out looking at the both static and dynamic balance after exergaming. Dynamic balance would specifically be interesting to look at over a period of exergaming training, as the majority of the games now in the commercial market (Kinect™, Playstation Move™) require dynamic movement patterns, as opposed to earlier games such as the Nintento Wii™ with balance board that required more static movements.

Although a robust method was used in the thesis to collect multiple sway parameters over multiple trials, more robust methods need to be developed in relation to outcome measures for postural control, as at current there are no "gold -standard" methods for the assessment of postural sway and, more specifically, there are no recommendations for exergaming literature. The literature regarding sway showed large variations in outcome measures and more standardized methods are needed to be applied to, not only to exergaming research, but measures of postural sway in general.

6.5.3   Postural Tracking

The results from the current thesis showed that the XBUS™ system could detect movements occurring in the upper body during postural control testing, however no correlations were found between postural sway at the upper body compared to the force plate. In order to gain a more in-depth analysis of postural movements at various locations in the human body during postural sway activities a more advanced motion capture system produced by XSENS™ called the MVN motion capture suit may be more suitable. The MVN

suit comes equipped with 17 MEMS inertial sensors which are custom built into a lycra suit. Using the MVN suit would allow movement patterns to be tracked whilst performing standing static balance, and has shown good reliability between Vicon (r 0.95-1.00, Theis et al., 2007).

6.5.4 <u>Movement Tracking</u>

As well as gaining information regarding postural movement during balance activities, it is now possible to accurately track movement and timing data in a marker free manner using the XBOX Kinect™. The Kinect motion sensor can measure three dimensional motion of a person with the use of Microsoft's 'Kinect for Windows SDK', to provide an Application Programmer's Interface (API) to the Kinect hardware. The API can be used with the Kinect sensor and its skeletal tracking software, providing a position estimate for 20 points on the user at 30Hz data capture (See Figure 14). The skeletal tracking algorithm includes major anatomical landmarks, including the head, shoulders, elbow, wrists, hand, hips, knees, ankles and feet. A recent paper by Galna et al., (2013) compared the accuracy of the Kinect compared to Vicon for measuring movement in healthy adults and Parkinson's disease (PD). Sequences of movements were produced including, side stepping, sit to stand, hand clasping, and toe tapping. The results showed that the Kinect measured the timing of movement repetitions extremely accurately (low bias, 95% limits of agreement < 10% of the group mean, ICCs > 0.9 and Pearson's r > 0.9). For spatial movements the Kinect related strongly related with values from the Vicon system (Pearson's r > 0.8) for most gross movements. Clark et al., (2012) concur with these results in that the Kinect can accurately track movements. Having marker less tracking can mean that postural movements and gross movements during can be accurately tracked throughout the gaming.

Figure 14: Skeletal Image of Kinect Sensor for 20 point joint estimation.
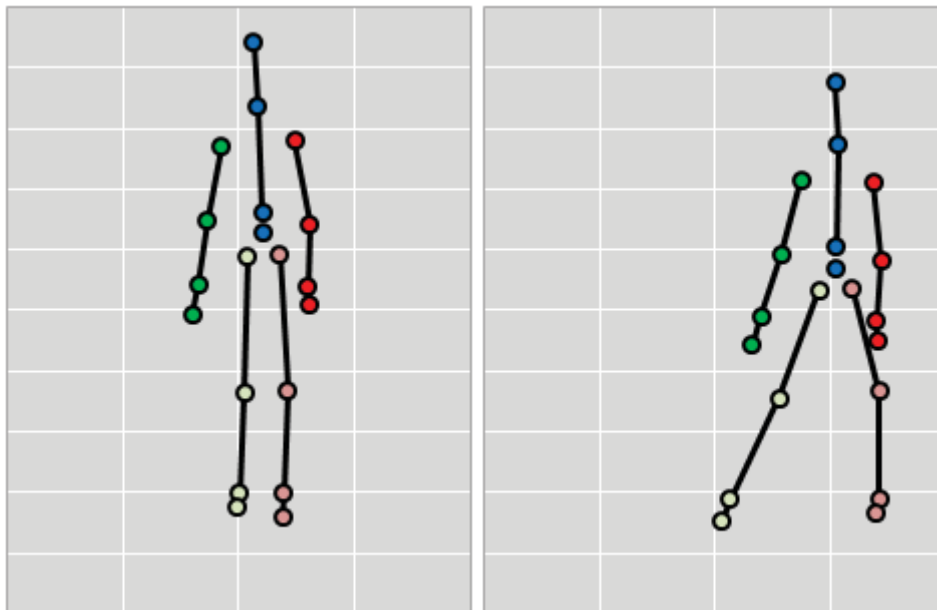
6.5.5   Study population

The current thesis provided valuable information regarding the effects of exergaming training on technology acceptance, flow and postural control; however a limitation was that the results can only be applied to healthy young adults. Future research is therefore needed to explore the effects of postural control on elderly and clinical conditions, as currently there is limited information regarding the potential effects of exergaming on musculoskeletal condition such as low back pain. Neurological conditions such as Parkinson's disease and multiple sclerosis also have limited information regarding levels of acceptance and flow experienced during exergaming and the effects on postural control. The use of commercial exergames have provided useful for healthy populations, but future work should tailor

commercial based exergames to clinical populations, as increased negative feedback when playing games that are too fast or complex may hinder motivation, exercise adherence, future performance and safety, (Lange et al., 2010). Developing specific exergames for clinical populations is a current area of development in exergaming research, especially using the Kinect™ sensor (Galna et al., 2013), with the aim of developing clinical based exergames for home based exercise.

6.5.6 <u>Kinect and Exergaming</u>

Technology is constantly changing at a rapid rate within today's society which can be seen in the current thesis. From the beginning of the thesis, the development of exergaming technology has rapidly changed in four years. From study one using the IREX™ system, the same software was implemented into the development of the Kinect™ (2010) using a hands-free controller system. Currently the Kinect is being re-developed again in a version called the XBOX one™ (2013) which is said to enable multiple motion tracking including tracking of heart rate and muscle forces. With the increase in development of new exergames it is important to understand the potential of the games; this can be achieved through multiple, physiological and psychological assessments. The results generated from this current thesis, offers an application of measurement for new exergaming systems for analysing behavioural intention, flow, postural control and biometric intensity. Along with current themes for future work, motion tracking may offer a more in depth analysis of what is occurring during the exercise sessions and when improvement is occurring, (for instance increase in range of motion) or reaction time.

7. OVERALL CONCLUSIONS

This section documents the pertinent conclusions in relation to the effects of exergaming compared to mirror-matched exercise on technology acceptance, flow and postural control in young healthy adults.

The findings from the current thesis can tentatively suggest that exergaming provides an enjoyable experience, experience episodes of flow and have the potential to enhance exercise behavioural intention (concordance). Results would also indicate the potential use of exergaming over mirror-matched exercise to improve postural control. Both results have the potential to be applied to clinical sub-groups to develop new methods of balance training using exergaming, and improve exercise behavioural intention (essentially concordance).

This research points to several main conclusions:

- Exergaming elicits higher levels of behavioural intention (concordance) to use the system as a means of exercise in the future compared to traditional exercise.
- Performance expectancy is the main determent of behavioural intention.
- Effort expectancy (ease of use) and social influences may have an effect on the levels of behavioural intention to use exergames.
- People are more in the flow during exergaming (4 weeks of training).
- Exergaming may offer an alternative method of balance training for healthy young adults.
- Assessment of postural control using inertial sensors, provides novel information for upper body movements, but is limited to assess postural control alone.
- Heart rate during exergaming can elicit moderate exercise intensity and be used as a method of daily exercise for 30 minutes of exercise a day in relation to the ACSM exercise guidelines (2009).

- Rate of Perceived exertion is less during exergaming compared to mirror matched gym based exercise with no virtual stimuli in healthy adults.

Further investigation is recommended in the following area:

- Applying UTAUT and flow to exergaming across various non- clinical and clinical sub groups to gain a wider understanding of their application to exergaming.
- Measures of dynamic balance, as exergaming is encouraging fast, rapid movements in multiple directions, therefore it would be useful to assess the effect this has on dynamic balance from a postural control perspective.
- Analyse the effects of sensory re-weighing following exergaming training on postural control.
- Movement tracking through exergames, to analyse movement and timing data for clinical populations with tailored home-based exergaming.

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9. APPENDICIES

9.1 Appendix 1: Ethical Approval

PRIVATE AND CONFIDENTIAL

Direct Line: 01642 342750

4th February 2009

Denis Martin

School of Health & Social Care

University of Teesside

Dear Denis

Study 017/09 – An investigation into the effects of exercising in a Virtual Reality environment for healthy volunteers Researcher: Gillian Barry Supervisor: Denis Martin

Decision: Approved with Advisory Comments

Thank you for your application to the School of Health & Social Care Research Governance and Ethics Committee.

The Committee reviewed and approved your application on 29th January 2009 and your study may proceed as it was described in your 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.

The Committee would request that you consider the following comments which are offered in the spirit of peer review and constructive criticism and do not affect the decision to approve.

Is it feasible to recruit 50 people by 16th February it would seem wise to allow more time.

The questionnaire subscales titles should not be in the version that people are given to fill in.

One questionnaire is titled motivation but should this be "Experience of …"?

The Information Sheet:

Please check that Prof. Shucksmith agrees to named as the contact should anyone want to raise a complaint?

Please check the date of withdrawal for consistency.

The diary is asking people to say that whether they have done their exercises or not. It would be better to give a list so that they could say that they have done say 1, 2, 3, 4, 5, 6 and how they felt during them.

The Consent Form:

Please check the date of withdrawal for consistency.

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

9.2   Appendix 2: <u>Recruitment Email</u>

Dear colleagues,

My name is Gillian Barry I am a Full Time PhD student in the School of Health and Social Care (Rehabilitation Science) and my PhD project is entitled "The effects of exergaming versus mirror matched exercise on Technology acceptance, flow and postural control in young healthy adults".

One part of this work is to investigate the use of a virtual rehabilitation system called IREX™ (Interactive rehabilitation exercise system) in exercise therapy. The IREX™ system is based on an extension of the type of thing seen every day on TV weather forecasts where the forecaster is shown standing in front of and interacting with, a changing weather map.

The study I am asking you to consider participating in aims to investigate any effects of exercising in a virtual rehabilitation environment by comparing exercising using the IREX™ Virtual Rehabilitation System, with the same exercise regime undertaken in a standard setting, by healthy volunteers.

If you are interested in taking part in this project then please read the attached Participant Information Sheet and contact me by email or phone.

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

Kind Regards

Miss Gillian Barry

9.3 Appendix 3: Poster

Recruitment notice to all staff and students for a PhD research project investigating the effects of exercising in a Virtual Reality environment for healthy volunteers

Do you work for, or study at, the University of Teesside?

Are you aged 18 or over?

Are you free from any injury or condition which would prevent you taking exercise?

Do you sit for most of your working day?

Do you participate in less than 30 minutes of moderate exercise most days of the week? (ACSM, 2007).

If you answered yes to these questions 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?

I am investigating the use of the IREX™ Virtual Rehabilitation System in exercise therapy. IREX™ is based on an extension of the type of thing seen every day on TV weather forecasts where the forecaster is shown standing in front of and interacting with, a changing weather map

If you decide to participate you would be asked to do a set of simple exercises for ten minutes each day and to attend for either a supervised exercise session, or a session with the IREX™ system, three times over the course of two weeks.

If you are interested then please contact my Director of Studies who will give you more information on what is involved and pass your contact details on to me.

Prof Denis Martin PhD - email, D.Martin@tees.ac.uk - Tel: 01642 38 4999

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

Thank you for taking the time to read this poster.

Miss Gillian Barry M.Sc, B.Sc (Hons).

9.4   Appendix 4: Participant Information Sheet

Title of study: An investigation into the effects of exercising in a Virtual Reality environment for non-active healthy volunteers.

Researcher: Ms Gillian Barry

Study identification Number _____

Purpose of the Study

My name is Gillian Barry I am a Full Time PhD student in the School, (Rehabilitation Science) and my PhD project is entitled, "The effects of exergaming verse mirror matched exercise on Technology acceptance, flow and postural control in young healthy adults".

One aspect of my PhD project is to explore the usability and people's acceptance of a virtual rehabilitation system called IREX™. The IREX system is based on an extension of the type of thing seen every day on weather forecasts where the forecaster is shown standing in front of and interacting with a changing weather map.

The study I would like to invite you to participate in is an investigation into the use of a VR environment for exercise behaviours of non-active adults, who spend 50% of their day or more in a seated position. I am looking at investigating how VR can enhance exercise behaviour and motivation from a basic snapshot experience of exercising in a VR.

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 them.

Why have I been invited to participate?

You have been invited to take part in this study because you are either a member of Staff or Student at Teesside University (TU). No matter whether you are staff or a student you must be aged over 18 years to take part. If you have any current, or history of any condition or

injury which means you should avoid the activities involved in the virtual rehabilitation game under study you cannot participate. Only physiotherapist staff will be excluded from this investigation, as the exercises require balance activities to which they will have experience of conduction. The questionnaire I am using was written in English so you will also have to be able to read, comprehend and write English to take part. Also instructions of exercise and demonstrations by the Chief Investigator (CI) will be carried out in English and no translations will be given.

What will be involved in the study?

Participants willing to take part in the investigation will be asked to perform a number of balance related games, either using the IREX™ VR system; which requires participants to stand in front of a 10foot green screen, whilst standing on an eight by ten florescent green foam mat positioned flat on the floor. Participants in the VR group will be required to wear their normal training shoes; the only additional equipment which is required is for the participants to wear a set of red gloves, which are used to track participant's movements. Movements will be live and participant's body image will be superimposed on to a flat screen TV monitor; when performing the exercises, these exercises will be non- recorded.

Exercise Session

During the VR exercise session participants will be required to play four games, each lasting from 45 seconds in duration with 15 second recovery. The games will be;

Formula Racing which is used to analyse mobility, postural control and weight shifting; the participants will be required to move from side to side as their body image is projected on screen to be driving a F1 car.

Snowboarding which is used to encourage mobility and total body exercises; the participants body image is projected on the screen as if they were on a snowboard and have

to go down a visual snowboard course by moving their feet and body forward and backwards and squatting during jumps.

Sharkbait which is used to analyse mobility, postural control and balance; The game requires you to stand in a sagittal plane and prevent the sharks from attacking you by moving your body left and right and squatting down.

Soccer - the participant's image is shown as a goalkeeper in virtual goal and moved their image to stop virtual balls entering the net.

Participants in the control (Exercise with no VR) will complete exercises similar to those performed on the IREX™ VR system. The exercises will be firstly demonstrated by the CI, who is a qualified sports scientist with experience, or delivering exercise prescription to a wide range of clients. The participants will be verbally instructed of what exercises to conduct.

After the games have been completed, or you choose to stop, you will be asked to fill out two questionnaires one of which is the adapted psychometric questionnaire (collects data on your behaviour intention towards exercise and virtual reality) and the second collects data on motivation levels. In total completing the questionnaires should take no more than five minutes of your time. So your total involvement in the study would last no more than ten minutes.

The data collection will commence from the 16/09/09 each participant will be required in total to attend three exercise sessions over a two week duration period.

What will be the benefit of taking part in the study?

The potential benefits of taking part in this study are to have the experience of exercising in a VR environment, and to educate participants on balance exercises.

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

There must always be some small risks involved in participation in any game that involves movement but for those who are eligible to take part this risk is, in the opinion of the research team, minimal.

Expenses and Payments

As this study is being undertaken as part of a PhD studentship I regret 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 or if you should have any complaints about the study.

Who has reviewed this study?

This project has been revised 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 May 2010 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 study identity number (which I have written on the top right hand corner of this sheet) to my Director of Studies, Dr Denis Martin (whose contact

details are at the end of this sheet) and your data will be removed and confidentially 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 Teesside University. 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 Teesside University. Electronic files containing the anonymised data will be kept on a password protected server at Teesside University. 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, while the study is underway, will be restricted to members of the research team – Prof Denis Martin, Prof Paul van Schiak, Dr Alasdair MacSween and Dr John Dixon.

How will the data be used?

The results of this study will be included in my PhD thesis and may be also be included in a publication in a peer reviewed journal and a conference presentation. 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 myself of Director of Studies:

Gillian Barry, MSc, BSc (Hons)

Parkside West Offices, Teesside University

g.barry@tees.ac.uk

Professor Denis Martin, PhD, Dphil,

 Parkside West Offices, Teesside University,

01642384999

d.martin@tees.ac.uk

Parkside West Offices, Teesside University

9.5 **Appendix 5: Informed consent**

Title: An investigation into the effects of exercising in a Virtual Reality environment for healthy non-active volunteers.

Researcher: Miss Gillian Barry

Please initial boxes

1. I confirm that I have read and understand the information sheet version 1.0 dated 07/12/09 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 be anonymised and only those members of the study team, who need to see it, in order to complete the study, will be allowed to see it.

3. I understand that 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 the University of Teesside.

5. I agree to the electronic files containing the anonymised data to be kept on a password protected server at the University of Teesside.

6. I am aware that participation in this study is voluntary and I have the right to withdraw at any point up until [30/05/10]. If I choose to withdraw I do not have to give a reason and none of my rights will be affected.

7. I confirm I am free of all exclusion criteria and meet the inclusion criteria as stated on the information sheet for this study.

CONSENT FORM **– This page printed as rear side of a single page**

8. I agree that the anonymised data collected on me during this study will be held securely (as described in the information sheet and in points four and five) for 5 years and that it may be used for future research only if an appropriate ethics committee has approved that research.

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

--------------------------- ------------- ------------------------------------

Name of Participant   Date   Signature

---------------------------- ------------- ---------------------------------

Researcher   Date   Signature

9.6 Appendix 6: Modified Technology acceptance questionnaires and original (Venkatesh et al., 2003) Study 1

An investigation into the effects of exercising in a Virtual Reality environment for non-active healthy volunteers: V 1.0 19/01/09: Modified Technology acceptance questionnaire – VR environment.

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 begun your exercise programme so please base your answers on your expectations or initial thoughts about the IREX™ system.

Performance Expectancy	Strongly Disagree						Strongly Agree
I found the IREX™ system useful to perform exercise	1	2	3	4	5	6	7
Using the IREX™ system allowed me to accomplish more exercises in the time available	1	2	3	4	5	6	7
Using the IREX™ system increased the efficiency of my exercise	1	2	3	4	5	6	7
If I use the IREX™ system I will experience more benefit	1	2	3	4	5	6	7

- **Effort Expectancy**   **Strongly Disagree**   **Strongly Agree**

- My interaction with the IREX™ system was clear and understandable   1   2   3   4   5   6   7

- It would be easy for me to become skilful using the IREX™ system   1   2   3   4   5   6   7

- I would find the IREX™ system easy to use   1   2   3   4   5   6   7

- Learning to operate the IREX™ system is easy for me   1   2   3   4   5   6   7

- **Social Influences**

- People who influence my behaviour think that I should use the IREX™ system   1   2   3   4   5   6   7

- People who are important to me think that I should use the IREX™ system   1   2   3   4   5   6   7

   The research team has been helpful in the use of the IREX™ system   1   2   3   4   5   6   7

- In general, the research team has supported the use of the IREX™ system   1   2   3   4   5   6   7

Facilitation Conditions

- I have the resources necessary to use the IREX™ system   1   2   3   4   5   6   7

- I have the knowledge necessary to use the IREX™ system for exercise purposes   1   2   3   4   5   6   7

- The research team would be of assistance if I experienced difficulties with the IREX™ system   1   2   3   4   5   6   7

Self- Efficacy   **Strongly Disagree**   **Strongly Agree**

I would complete exercises using the IREX™ 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 if I got stuck   1   2   3   4   5   6   7
- If I had a lot of time to exercise using the IREX™ system   1   2   3   4   5   6   7
- If I just had an online help facility for assistance   1   2   3   4   5   6   7

Behaviour Intention to use the System

- I would intend to use the IREX™ system in the next 3 months if it was readily available   1   2   3   4   5   6   7
- I predict I would use the IREX™ system in the next 3 months, if it was readily available   1   2   3   4   5   6   7
- I plan to use the IREX™ system in the next three months if it was readily available   1   2   3   4   5   6   7

An investigation into the effects of exercising in a Virtual Reality environment for non-active healthy volunteers: V 1.0 19/01/09: Modified Technology acceptance questionnaire – Gym type environment.

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 begun your exercise programme so please base your answers on your expectations or initial thoughts about the environment in which you will exercise.

Performance Expectancy	**Strongly Disagree**						**Strongly Agree**

- I found the environment I exercised in useful to perform exercise   1   2   3   4   5   6   7
- The environment I exercised in allowed me to accomplish   more exercises in the time available   1   2   3   4   5   6   7
- The environment I exercised in increased the efficiency of my exercise   1   2   3   4   5   6   7
- The environment I exercised in means I will experience more benefit   1   2   3   4   5   6   7

    Effort Expectancy

- My interaction with the environment I exercised it was clear and understandable   1   2   3   4   5   6   7
- It would be easy for me to become skilful in the environment I exercised in   1   2   3   4   5   6   7
- I would find the environment I exercised in easy   1   2   3   4   5   6   7
- Learning to exercise in the environment I exercised in is easy for me   1   2   3   4   5   6   7

Strongly Disagree   **Strongly Agree**

Social Influences

- People who influence my behaviour think that I should exercise in the environment I exercised in   1   2   3   4   5   6   7
- People who are important to me think that I should exercise in the environment I exercised in   1   2   3   4   5   6   7
- The research team has been helpful in the use of the environment I exercised in   1   2   3   4   5   6   7
- In general, the research team has supported the use of the environment I exercised in   1   2   3   4   5   6   7

Facilitation Conditions

- I have the resources necessary to use the environment I exercised in   1   2   3   4   5   6   7
- I have the knowledge necessary to use the environment I exercised in   1   2   3   4   5   6   7
- The research team would be of assistance if I experienced difficulties in using the environment I exercised in   1   2   3   4   5   6   7

Self- Efficacy

I would complete exercise sessions in the environment I exercised in …

- 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 if I got stuck   1   2   3   4   5   6   7
- If I had a lot of time to exercise using the sessions   1   2   3   4   5   6   7
- If I just had an online help facility for assistance   1   2   3   4   5   6   7

Behavioural intention to use the system   **Strongly Disagree**   **Strongly Agree**

- I would intend to use the environment I exercised in   1   2   3   4   5   6   7

  in the next 3 months, if it was readily available

- I predict I would use the environment I exercised in   1   2   3   4   5   6   7

  in the next 3 months, if it was readily available

- I plan to use the environment I exercised in   1   2   3   4   5   6   7

9.7   Appendix 7: Original UTAUT Questionnaire

Original Technology Acceptance Questionnaire (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.

Affect1: 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 organization 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.

An investigation into the effects of exercising in a Virtual Reality environment for non-active healthy volunteers: V 1.0 19/01/09

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 before you begun your exercise programme so please base your answers on your expectations or initial thoughts about exercise.

	Strongly Disagree				Strongly Agree
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

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

1   2   3   4   5

have been thinking of me.

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

9.9   Appendix 9: Surface Electromyography Placement

Placements of the SEMG were in accordance with Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines for electrode placement SEMG was measured on 5 muscles (three in the trunk and two of the lower limb) for the assessment of balance.

Firstly if hair was present over the area of skin where the electrodes were going to be placed participants were asked to shave using a single use disposable razor. In all cases the area of skin was cleaned with a single use disposable alcohol pad to improve conductivity. Hypoallergenic conductance gel (LectronII, ECG-TENS) was applied to each electrode to improve electrical conductance between the skin and the electrode. All electrodes were held in position using hypoallergenic tape. A pre-gelled ground reference electrode (Blue Sensor®) was placed on the tibial tuberosity of the non-dominant kicking leg prior to any surface electrodes. Dominant kicking leg was assessed by asking the participants "which leg would you kick a football with". The electrodes where checked once they were attached to the skin to verify that they were all picking up signals.

The primary trunk muscles were para-spinal (PS) (left and right side, and the rectus abdominus (RA). For the lower limb analysis medial Gastrocnemius (MG), and tibialis anterior (TA), were analysed. Location of each electrode was in accordance with SENIAM guidelines and literature.

Para spinal muscles: the electrode was located at the L4 vertebral level (Mullington *et al.,* (2007); Masumoto *et al.,* (2006).

Rectus abdominus; fibre orientation was approximated at the level of the anterior superior iliac spine, 2 cm lateral to the midline, at L4 vertebral level (Santos *et al.,* 2009).

Tibialis anterior; the electrode was placed 1/3 on the line between the tip of the fibula and the tip of the medial malleolus (SENIAM), the best location can be achieved in a sitting or supine position (Kleissen *et al.,* 1997).

Medial Gastrocnemius; electrodes were places over the area of the greatest muscle bulk (SENIAM) and orientated at a 15° medial angle, achieved by getting the subject to stand on their toes, with their heels just lifted off the ground (Kleissen *et al.,* 1997).

All electrodes were placed by the GB and any loose wires were secured to minimise any *slip or trip* risk

In order to make sure that all of the electrodes where positioned accurately and to check the connectivity of the SEMG signals participants were asked to produce the following movements against manual resistance form GB whilst the participant sat on a plinth:

Right and Left Paraspinal- (RP &LP) – resisted back extension

Rectus abdominus (RA) - resisted trunk flexion (sit- up)

Tibialis anterior (TA) - resisted ankle dorsiflexion with inversion.

Medial *Gastrocnemius* (MG) – resisted plantar flexion of the dominant kicking foot (raising on toes).

9.10 Appendix 10: IREX camera Set-up

Camera set up IREX

At each session the system was configured according to manufactures instructions. The camera set up is firstly performed (see image 1) as too much external light can affects the image quality, likewise darkness can also produce distorted images.

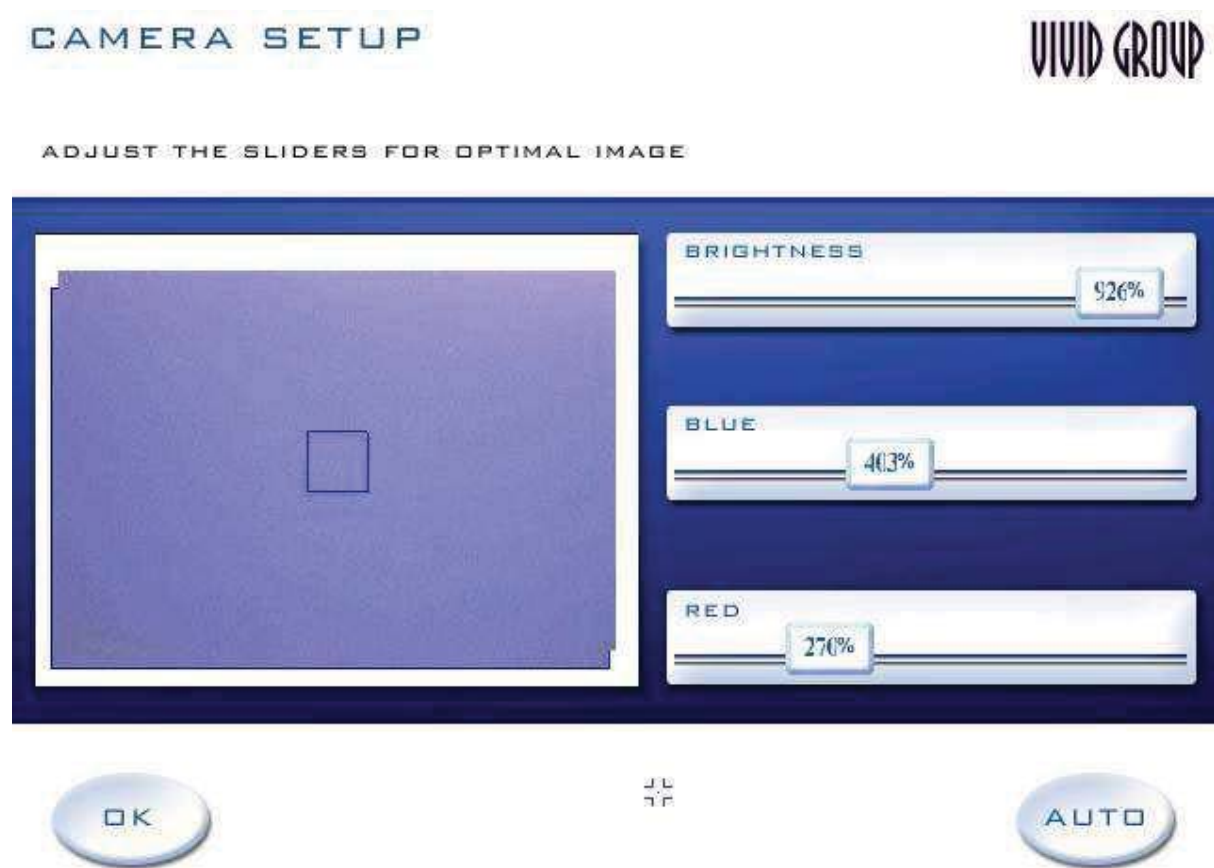Image 1: Screen shot of Camera Setup (GesturTek manual)

After clicking the AUTO button from the Camera Setup window, GB got the participants to hold a sheet of clean white paper in front of the blue square on the window at the distance you would normally stand (see Image 1). When this was complete, GB left clicked on OK and the settings were automatically be adjusted. This procedure lasted roughly 10-20 seconds.
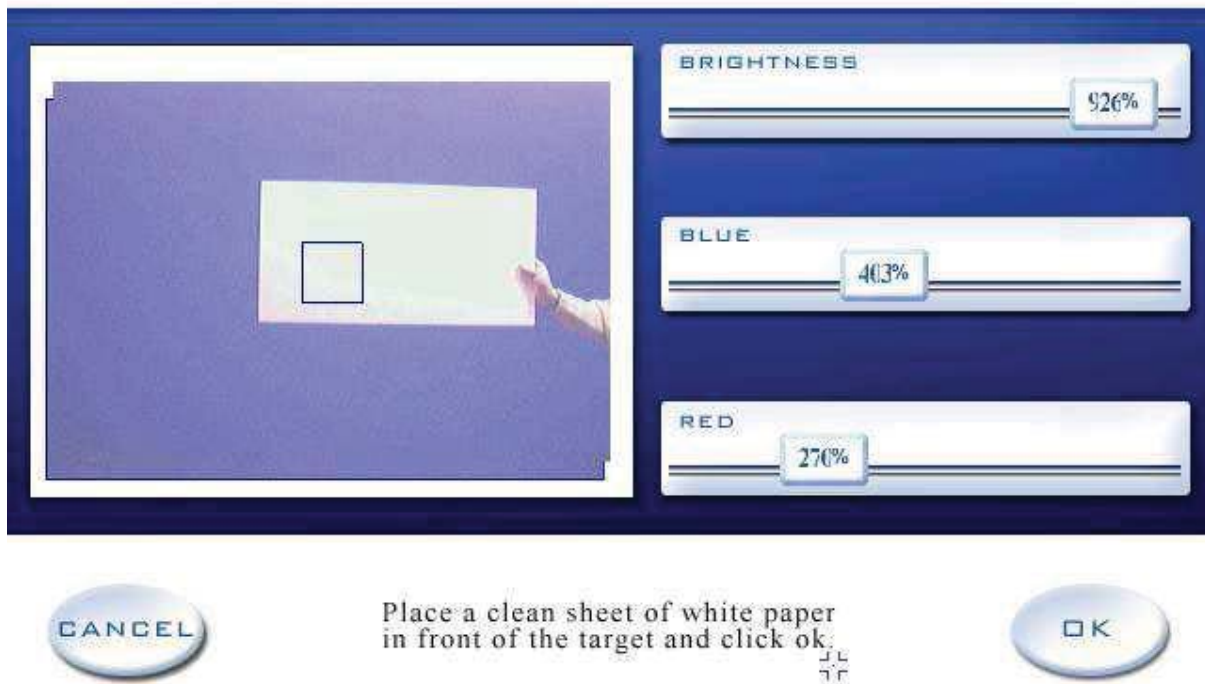
Image 2: Screen shot of Camera calibration (GesturTek manual)

The next step was to configure the image set-up, firstly this required the back drop of the green screen to be the only image in view of the camera (Image 3) GB then Left clicked on the SAMPLE button to begin the background removal process. Once the background has been removed GB got the participant to stand back in front of the camera (Image 4), if some of the green backdrop was still appearing in the image with the participant in, then GB used the THRESHOLD slider bar to remove the remaining backdrop image. Once a clear image of the participant with no backdrop was available then testing could begin. If the image is not clear, (see image 5) then the above procedure would need to be repeated, as unclear images would effects the game play and cause distortion of the images.

In that time the system captures the body image and configures to take out any external background (i.e. the green screen background is removed and the image alone is then included in the game animation). Participants performed exercises playing four pre-programmed games selected to optimise balance training.

SIMPLE SETUP

VIVID GROUP

Step 1:
Step out of the
camera image
and press Sample.

SAMPLE

Step 2:
Step into the camera
and adjust the sliders.

SAVE KEY

THRESHOLD

1.84

BACK

GO

Image 3 simple set up of background with no image on screen
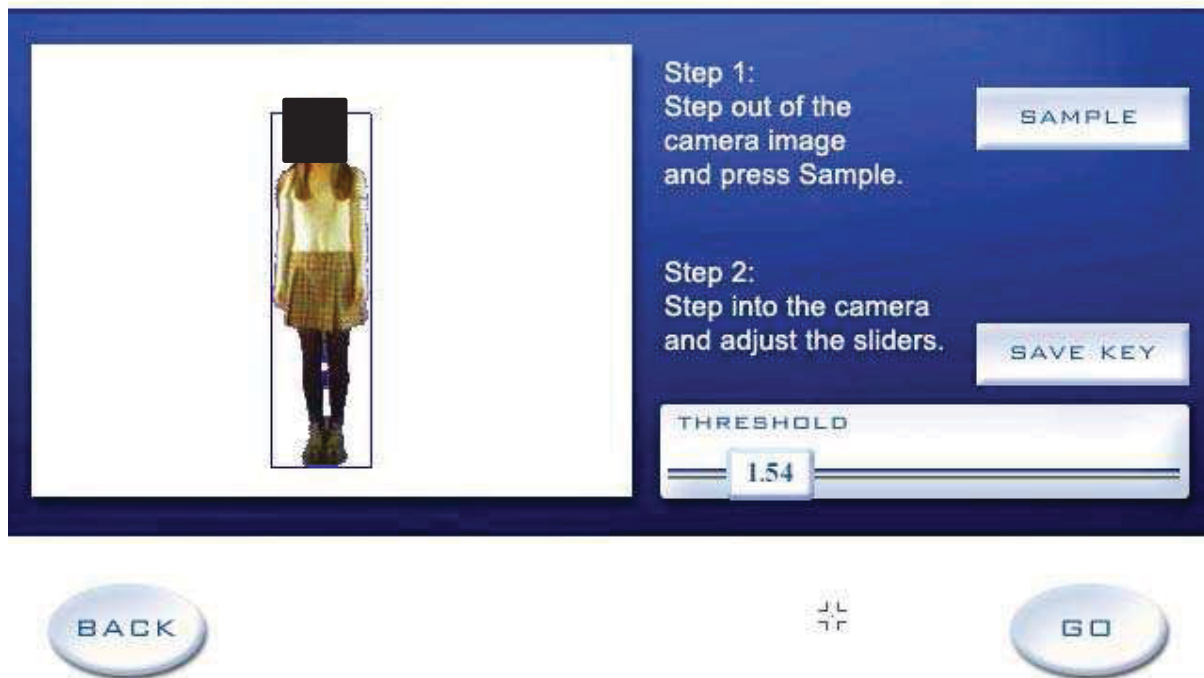
Image 4 Participant image with background removal.

Image 5: Distorted background which would need re-calibration due to an unclear image.

9.11 Appendix 11: Home Exercises

An investigation into the effects of exercising in a Virtual Reality environment for healthy volunteers. Home Exercise Instructions, V 1.0, 19/01/08

Please do your exercises as you were taught them by Gillian in your first session – try to do them at home, or in your office if you prefer, for ten minutes once every day for the two weeks <u>except</u> on the three days when you come in for a supervised exercise session with Gillian - on those days don't do any exercises other than in the session with Gillian.

The exercises are all designed to be easy to do and involve simple movements.

Please remember always do the exercises in your own comfortable range – <u>never</u> try to over-reach or extend further than where you are comfortable

You should do the exercises in the rhythm that feels comfortable to you and please take a rest whenever you feel you need one.

Do the different movements in the order you were taught them – this is repeated below to help you remember – and try to do a set of 20 repetitions of each movement and keep going for ten minutes. Please repeat the sequence of exercises, at your own pace, until you have been exercising for ten minutes.

Firstly there is trunk flexion/extension, in this you should put your hands on your hips and bend forward to a comfortable point – then keeping your hands on your hips straighten up and then bend your body back as far as is comfortable. Remember it is essential that you don't try and over stretch whilst performing any of these exercises, they should be performed within your own individual comfortable range.

Don't look upwards when performing the backwards movements as this may make it more difficult to keep your balance. This should be performed ten times forwards and back to make up the set of twenty repetitions.

The next exercise is trunk side-flexion; you should stand with your feet about shoulder width apart and your arms at either side of your body. From this position slide your hands down each side of your body, one side at a time - e.g. start by sliding your right hand down the right hand side of your right leg so your body bends sideways, then return back to standing straight and repeat the movement sliding your left hand down the outside of your left leg. As with all your exercises the movement should be performed in a controlled manor and only to where you are comfortable – don't worry about how far you can reach just go as far as is comfortable for you. This should be performed ten times on each side to make up the set of twenty repetitions.

Trunk rotation is the next exercise here you rotate your body around the long axis of your spine. Start by standing with your feet about shoulder width apart with your hands placed on your hips. Then staying standing up tall twist your body round to one side as far as is comfortable - if you start by turning to the right as you do so your left arm will come round to point nearer to the front. Once you have turned as far as is comfortable for you to one side turn back to the centre and repeat by turning to the other side. This movement should be performed ten times to each side to make up the set of twenty repetitions.

Next you should do the upper limb movements which are flexion/extension and abduction/adduction. Start by standing with your feet about shoulder width apart and then reach forward with both hands (keeping your elbows straight) as if you were

trying to reach an object placed in front of you at chest height as far as is comfortable. Then return your arms to your sides and reach straight behind yourself with both hands (keeping your elbows straight), again, only as far as is comfortable. This movement should be performed ten times forwards and back to make up the set of twenty repetitions.

For abduction/adduction start in the same position but this time raise both your arms at the same time out to the side, and then lower them back down to your sides and then reach them across your body to the opposite side (crossing your arms over your chest). This movement should be performed ten times out to the side and then across your chest to make up the set of twenty repetitions.

Last of all do the lower limb movements which involve stepping forwards and back and side-to-side. Start by standing with your feet about shoulder width apart and your arms by your sides and then step forward with your right foot so that your right knee bends to approximately 90° (a right angle) – like you were taking a big step forwards. If you don't manage to go far enough forwards to reach a right angle bend in your knee <u>don't worry about it</u> just go as far as you feel is comfortable. Then bring the right leg back to the starting position and do the same with the left leg. This movement should be performed ten times with each leg to make up the set of twenty repetitions.

Then start by standing with your feet about shoulder width apart and your arms by your and step backwards with your right leg as far as is comfortable, step back up and the do the same movement with your left leg. Again, this movement should be performed ten times with each leg to make up the set of twenty repetitions.

Finally starting in the same position as for the other leg exercises take a step out to the right with your right leg so your whole body moves to the right, then come back to the starting position and repeat the movement stepping out to the left. As with all the movements only step out as far as you are comfortable to do. This movement should be performed ten times to each side to make up the set of twenty repetitions.

At no time should you feel any pain or discomfort – these exercises are all designed specifically to be gentle and are very safe even for those people who don't normally take exercises. You may feel a little muscular heaviness, or ache, a while after you have done the exercises, or maybe the next morning but that's perfectly normal. It's just your body adjusting to the unaccustomed exercise – the kind of feeling you get in your legs if you go for a long walk, or maybe if you are gardening, or doing a lot of house work, when you are a little out of shape. Most people know this feeling and know it's just a normal part of exercising when you're not used to it. If you should feel any pain or other discomfort, during or after the exercises, then you must stop exercising <u>immediately.</u> If the pain or discomfort doesn't subside when you stop exercising, or at most within ten minutes of your stopping, or is severe, then seek medical advice as soon as possible. You <u>must not</u> start exercising again until your medical advisor says it is ok to do so.

9.12 Appendix 12: Example of normal and corrupt postural sway data

Normal unipedal data output for AP and ML sway
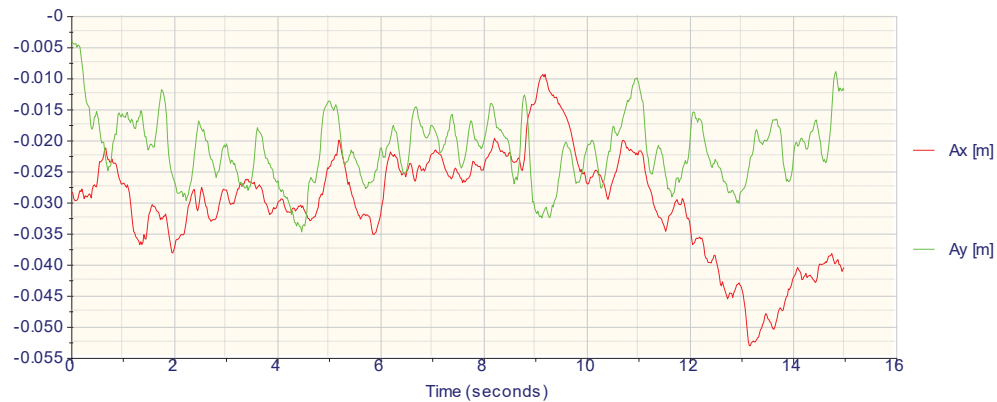
Unipedal output error in data points – no data reading available as all points are below threshold.
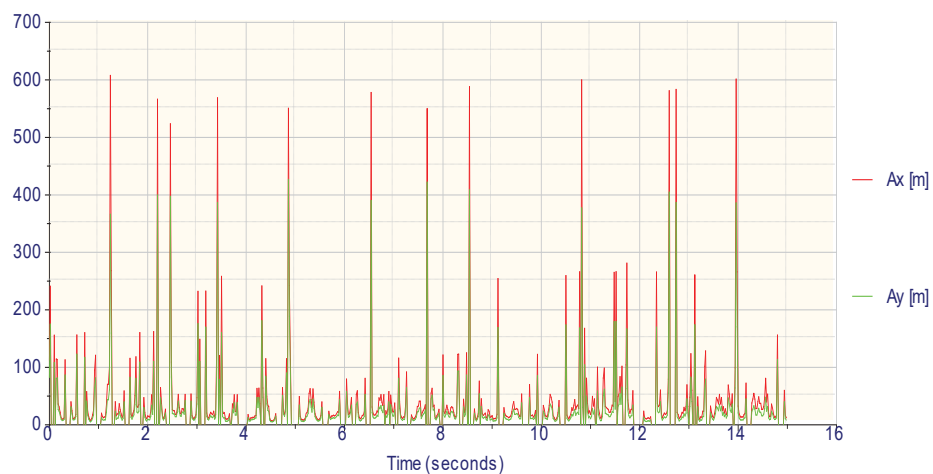
9.13 Appendix 13: Ethical Approval Study 2.

PRIVATE AND CONFIDENTIAL

Direct Line: 01642 384124

5 January 2011

Denis Martin

School of Health & Social Care

Teesside University

Dear Denis

Study No 264/10: An investigation into the effects of balance training using a virtual environment for healthy volunteers. Researcher: Gillian Barry. 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. 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

9.14 Appendix 14: Recruitment Email

Dear colleagues,

My name is Gillian Barry I am a Full Time PhD student in the School of Health and Social Care (Rehabilitation Science) and my PhD project is entitled "The effects of exergaming versus mirror matched exercise on Technology acceptance, flow and postural control in young healthy adults".

 One part of this work is to investigate the use of the XBOX Kinect™ versus mirror matched gym based exercise with no virtual stimuli on levels of technology acceptance, flow and postural control over a 4-week exercise programme.

The study I am asking you to consider participating in aims to investigate any difference between exercising in a virtual rehabilitation environment using the XBOX Kinect™ Virtual Reality System, with the same exercise regime undertaken in a standard setting, by healthy volunteers.

If you are interested in taking part in this project then please read the attached Participant Information Sheet and contact me by email or phone.

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

Kind Regards

Miss Gillian Barry

If you are interested in the current investigation then please feel free to contact myself via email at: G7099032@tees.ac.uk, Telephone at: 07783993648.

9.15 Appendix 15: Recruitment Poster

An Investigation into the Effects of Balance Training and Exercise Using a

Virtual Environment for Healthy Volunteers

Interactive Exercise for Everyone!!

- Do you want to try some new exercise?
- Try something Novel and Exciting
- Do you like computer gaming and exercise together?

The study I am asking you to consider participating in aims to investigate any difference between exercising in a virtual rehabilitation environment using the XBOX Kinect™ Virtual Reality System, with the same exercise regime undertaken in a mirror matched gym based exercise with no virtual stimuli by healthy volunteers.

Virtual reality is a novel and exciting area new to rehabilitation sciences. Recent findings on young participants show that virtual reality (VR), when paired with exercise, enhances mood, thus increasing enjoyment and energy, (Plante *et al.,* 2003).

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

If you are interested in the current investigation then please feel free to contact myself via email at: **G7099032@tees.ac.uk,** Telephone at: **07783993648.**

9.16 Appendix 16: Participant information sheets (study 2)

Title of study: An investigation into the effects of balance training using a virtual environment for healthy volunteers.

Researcher: Ms Gillian Barry

Study identification Number _____

Purpose of the Study

My name is Gillian Barry I am a Full Time PhD student in the School of Health and Social Care, (Rehabilitation Science) at Teesside University (TU) and my PhD thesis is entitled, "The effects of exergaming verse mirror matched gym based exercise with no virtual stimuli on technology acceptance, immersion and postural control in young healthy adults".

One aspect of my PhD project is to explore the usability and people's acceptance of a virtual system called the XBOX Kinect™. The Kinect™ system is a commercially available system and works in conjunction with the XBOX 360 games console. The Kinect™ allows gaming and exercise to be performed with no controller and is hands free devise which picks up the "players" body image.

The study I would like to invite you to participate in is an investigation looking into whether exercising in a VR can enhance exercise behavior in a group of healthy volunteers.

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 them.

Why have I been invited to participate?

You have been invited to take part in this study if you are healthy and are between the ages of 18- 65years old. If you have any current, or history of any condition or injury which means

you should avoid the activities involved in the virtual reality games under study you cannot participate. If you are allergic to any hypoallergenic gel or tape then you will also be excluded from the study. The set of questionnaire's I am using was written in English so you will also have to be able to read, comprehend and write English to take part. I will demonstrate and instruct the exercises, all of which will be carried out in English and no translations will be given.

What will be involved in the study?

Outcome Measures

If you are willing to take part in the investigation and give your informed consent to state this then you will report to the physiotherapy laboratory in the Constantine Building at TU for your first exercise session. During your first session your demographic data consisting of your height, weight and dominant kicking leg will be recorded, during this time you will be asked to take your shoes and socks off for the height and weight to be recorded. Only the research team will have access to this data and by no means will any names be published as all data is confidential. After demographic data has been reordered small surface electrodes will be placed on your dominant kicking leg over three muscles; Gastronomies Medialis (GAS) Tibialis Anterior (TA) and Soleus (S) all of these muscles are in the lower leg (below the knee). Prior to electrode placement you will be asked to shave the area where the electrode is going to be placed using a single use disposable razor, if necessary, and the skin will be cleaned with a single use disposable alcohol pad to improve conductivity. Hypoallergenic conductance gel (LectronII, ECG-TENS) will be applied to each electrode to improve electrical conductance between the skin and the electrode. All electrodes were held firmly in position using hypoallergenic tape. A pre-gelled ground reference electrode (Blue Sensor®) will be placed on the knee cap of the non-dominant kicking leg prior to any surface electrodes. As the electrodes will be placed below the knee you are required to wear loose fitting trousers which roll up to knee level or if you prefer wear shorts.

Once the electrodes are attached you will be asked to perform a set of maximal voluntary isometric contractions (MVICs), you will be asked to perform repetitions on the dominant kicking leg on the Biodex system. This system is used in order to distinguish maximum muscle contraction during isometric movements and therefore any muscle contraction obtained during standing balance can be taken as a percentage of maximal contraction. You will be asked to perform maximum contractions on only the dominant kicking leg. A standard warm- up period will be conducted prior to MVIC's this will include walking 100m in the laboratory followed by a practice and familiarization of the Biodex protocol.

After performing the MVICs your balance will be assessed. You will stand quietly on a Kistler force plate for five repetitions of unipedal (one-legged) standing balance, each trial will last 30 seconds with a 30 seconds rest between each test. After the completion of your standing balance the electrodes will be removed you will also be asked to wear a Polar Heart Rate Monitor® (HR). The HR Monitor will record your HR continuously throughout the exercise sessions. The HR Monitor comprises of a soft hypoallergenic band of approximately 15 cm length and 4 cm width which is placed on the mid-line of the chest (below any clothing) and is held in place by an adjustable belt. You will attach this belt yourself around your chest and there will be a dedicated place in the laboratory for you to go and attach the belt in private.

Before you take part in the exercise sessions you will be asked to fill out two questionnaires which should take no longer than five minutes to do so. After completion of the questionnaires you will perform your exercise session in your pre-selected exercise group either exercise in a VR environment or exercise in a gym based environment.

If you are in the VR exercise group you will be using the XBOX Kinect™ VR system; which requires you to stand in front of a television monitor and perform virtual based exercises using an avatar (a virtual character) as your point to movement. Or if you are not in the VR group you will be in the standardized exercise group which receives a one to one instruction exercise session with no VR. Everyone will be required to come to the exercise sessions

with appropriate training shoes suitable for a gym environment. When performing the exercises, the exercises will not be recorded. All sessions will take place at the TU in the Constantine building. You will be asked to wear loose fitting clothing and flat shoes when reporting for testing. All exercise is done at your own pace and if at and you are free to rest for longer periods of times during the exercise if you wish to do so.

Exercise Session

Exercise sessions will be selected based on balance performance activities from the Kinect sports, EA sports 2, Kinect adventures and your shape. Kinect sports offers six interactive games of Soccer, Volleyball, Track & Field, Bowling, Table Tennis or Boxing - with Full Body Play and EA2 sports and interactive fitness game and your shape is a gym based exercise game similar to that of the Wii fit, which enables the you to gain feedback on their range of movements (ROM) and performance during the activities. The use of the feedback system allows you to gain perfection during the movements and also gain confidence to increase the intensity of the games.

For those of you in the control group (Exercise with no VR) you will complete exercises similar to those performed on the XBOX Kinect™ VR system. The exercises will be firstly demonstrated by me, a qualified sports scientist with experience, or delivering exercise prescription to a wide range of clients. You will be verbally instructed of what exercises to conduct. In terms of progression the intensity of the exercises will gradually be increased over the four week exercise period, progression will be made my adding external equipment (i.e. wobble board/ thera bands) and by increasing the number of repetitions. All effort will be made by me to mimic the same exercise movements that would be used in the VR group.

After the games have been completed, or you choose to stop, you will be asked to fill out two questionnaires one of which is the adapted questionnaire (collects data on your behavior intention towards exercise and virtual reality) and the second collects data on your flow

state. In total completing the questionnaires should take no more than five minutes of your time

The data collection will commence from the 10/01/11 each participant will be required in total to attend twelve supervised exercise sessions over a four week duration period.

What will be the benefit of taking part in the study?

We make no claims that participation in this study will be of any direct benefit to you but physical exercise has been shown to be beneficial in other studies.

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

There must always be some small risks involved in participation in any exercise or game that involves movement but for those who are eligible to take part this risk is, in the opinion of the research team, minimal.

Expenses and Payments

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

What happens if something goes wrong?

This study is covered by the TU 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) or telephone: 01642 342750 in the first instance or if you should have any complaints about the study.

Who has reviewed this study?

This project has been revised 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 the 30/01/11 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 study identity number (which I have written on the top right hand corner of this sheet) to my Supervisor Prof Denis Martin (whose contact details are at the end of this sheet) and your data will be removed and confidentially destroyed.

Confidentiality, Anonymity and data storage.

All information collected during this study will be stored in accordance with the Data Protection Acts (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 TU. 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 TU. Electronic files containing the anonymised data will be kept on a password protected server at TU. The anonymised data collected during this study will be held securely (as described above) for 20 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, while the study is underway, will be restricted to members of the research team – Prof Denis Martin, Prof Paul van Schiak, Dr Alasdair MacSween and Dr John Dixon.

How will the data be used?

The results of this study will be included in my PhD thesis and may be also be included in a publication in a peer reviewed journal and a conference presentation. 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 myself or my Supervisor:

Gillian Barry

Phoenix Building, Teesside University

g.barry@tees.ac.uk

OR

Prof Denis Martin, PhD, Dphil,

Parkside West Offices, Teesside University

01642384999

d.martin@tees.ac.uk

9.17 <u>Appendix 17: Informed Consent Study 2</u>

Informed Consent Form

Title: An investigation into the effects of balance training using a virtual environment for healthy volunteers.

Researcher: Miss Gillian Barry

Please initial boxes

1. I confirm that I have read and understand the information sheet (version 1.0 dated 23/12/10) for this study. I have had the opportunity to ask questions and had these answered satisfactorily.

2. I understand that data relating to me will be kept confidential to the study team and no identifiable information will be released unless required by law.

3. I agree to the anonymised data being held for up to 20 years and to be used for future research if an appropriate ethics committee has approved that research.

4. I am aware that participation in this study is voluntary and I have the right to withdraw at any point up until [30/01/11].

5. I confirm I am able to take part in this study and that I meet the criteria stated on the information sheet for this study.

6. I agree to take part in the study

Name of Participant   Date   Signature

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Name of Witness   Date   Signature

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9.18 Appendix 18 UTAUT (study 2)

An investigation into the effects of balance training and exercise using a virtual environment for healthy volunteers.

Modified Technology acceptance questionnaire – VR Environment.

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 program so please base your answers on your expectations or initial thoughts about the virtual reality system.

Performance Expectancy	**Strongly Disagree**						**Strongly Agree**
I found the XBOX Kinect system useful to perform exercise	1	2	3	4	5	6	7
Using the XBOX Kinect system allowed me to accomplish more exercises in the time available	1	2	3	4	5	6	7
Using the XBOX Kinect system increased the efficiency of my exercise	1	2	3	4	5	6	7
If I use the XBOX Kinect system I will experience more benefit	1	2	3	4	5	6	7

Strongly Disagree   **Strongly Agree**

Effort Expectancy

- My interaction with the XBOX Kinect system was clear and understandable   1   2   3   4   5   6   7
- It would be easy for me to become skilful using the XBOX Kinect   1   2   3   4   5   6   7
- I would find the XBOX Kinect system easy to use   1   2   3   4   5   6   7
- Learning to operate the XBOX Kinect system is easy for me   1   2   3   4   5   6   7

Social Influences

- People who influence my behaviour think that I should use the XBOX Kinect system   1   2   3   4   5   6   7
- People who are important to me think that I should use the XBOX Kinect system   1   2   3   4   5   6   7

   The research team has been helpful in the use of the XBOX Kinect system   1   2   3   4   5   6   7

- In general, the research team has supported the use of the XBOX Kinect system   1   2   3   4   5   6   7

Facilitation Conditions

- I have the resources necessary to use the XBOX Kinect system   1   2   3   4   5   6   7
- I have the knowledge necessary to use the XBOX Kinect system for exercise purposes   1   2   3   4   5   6   7
- The research team would be of assistance if I experienced difficulties with the XBOX Kinect   1   2   3   4   5   6   7

	Strongly Disagree	**Strongly Agree**

Self- Efficacy

I would complete exercises using the XBOX Kinect 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 if I got stuck   1 2 3 4 5 6 7
- If I had a lot of time to exercise using the XBOX Kinect system   1 2 3 4 5 6 7
- If I just had an online help facility for assistance   1 2 3 4 5 6 7

Behaviour Intention to use the System

- I would intend to use the XBOX Kinect system in the next 3 months if it was readily available   1 2 3 4 5 6 7
- I predict I would use the XBOX Kinect system in the next 3 months, if it was readily available   1 2 3 4 5 6 7
- I plan to use the XBOX Kinect system in the next three months if it was readily available   1 2 3 4 5 6 7

An investigation into the effects of balance training and exercise using a virtual environment for healthy volunteers.

Modified Technology acceptance questionnaire – Gym type environment.

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 begun your exercise programme so please base your answers on your expectations or initial thoughts about the environment in which you will exercise.

Performance Expectancy   **Strongly Disagree**   **Strongly Agree**

- I found the environment I exercised in useful to perform exercise   1   2   3   4   5   6   7
- The environment I exercised in allowed me to accomplish   more exercises in the time available   1   2   3   4   5   6   7
- The environment I exercised in increased the efficiency of my exercise   1   2   3   4   5   6   7
- The environment I exercised in means I will experience more benefit   1   2   3   4   5   6   7

    Effort Expectancy

- My interaction with the environment I exercised it was clear and understandable   1   2   3   4   5   6   7
- It would be easy for me to become skilful in the environment I exercised in   1   2   3   4   5   6   7
- I would find the environment I exercised in easy   1   2   3   4   5   6   7
- Learning to exercise in the environment I exercised in is easy for me   1   2   3   4   5   6   7

| | **Strongly Disagree** | **Strongly Agree** |

Social Influences

- People who influence my behaviour think that I should exercise in the environment I exercised in   1   2   3   4   5   6   7
- People who are important to me think that I should exercise in the environment I exercised in   1   2   3   4   5   6   7
- The research team has been helpful in the use of the environment I exercised in   1   2   3   4   5   6   7
- In general, the research team has supported the use of the environment I exercised in   1   2   3   4   5   6   7

Facilitation Conditions

- I have the resources necessary to use the environment I exercised in   1   2   3   4   5   6   7
- I have the knowledge necessary to use the environment I exercised in   1   2   3   4   5   6   7
- The research team would be of assistance if I experienced difficulties in using the environment I exercised in   1   2   3   4   5   6   7

Self- Efficacy

I would complete exercise sessions in the environment I exercised in …

- 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 if I got stuck   1   2   3   4   5   6   7
- If I had a lot of time to exercise using the sessions   1   2   3   4   5   6   7
- If I just had an online help facility for assistance   1   2   3   4   5   6   7

Behaviour Intention to use the System   **Strongly Disagree**   **Strongly Agree**

- I would intend to use the environment I exercised in   system in the next 3 months if it was readily available   1 2 3 4 5 6 7

- I predict I would use the environment I exercised in   in the next 3 months, if it was readily available   1 2 3 4 5 6 7

- I plan to use the environment I exercised in the next three months if it was readily available   1 2 3 4 5 6 7

9.19 Appendix 19: Borg Rate of Perceived Exertion (RPE) Scale.

Rating of Perceived Exertion (RPE)

6	No exertion at all
7	
	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Vey hard
18	
19	Extremely hard
20	Maximal exertion

9.20 Appendix 20 Surface electromyography procedure

If hair was present over the area of skin where the electrodes were going to be placed participants were asked to shave using a single use disposable razor. In all cases the area of skin was cleaned with a single use disposable alcohol pad to improve conductivity. All the electrodes used a double sided sticky tape in order to stick to the skin. Additionally hypoallergenic tape was used to keep the electrodes in place. A pre-gelled ground reference electrode (Blue Sensor®) was placed on the tibial tuberosity of the non-dominant kicking leg prior to any surface electrodes (see Appendix 20 for full detail of electrode placements). Dominant kicking leg was assessed by asking the participants "which leg would you kick a football with". The electrodes where checked once they were attached to the skin to verify that they were all picking up signals.

Placements of the SEMG were in accordance with Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines for electrode placement SEMG was measured on 3 muscles in the lower leg.

The muscles were medial Gastrocnemius (MG), tibialis anterior (TA), and Soleus (S) were analysed. Location of each electrode was in accordance with SENIAM guidelines and literature.

Medial Gastrocnemius; electrodes were places over the area of the greatest muscle bulk (SENIAM) and orientated at a 15° medial angle, achieved by getting the subject to stand on their toes, with their heels just lifted off the ground (Kleissen *et al.,* 1997), (see Appendix 20).

Tibialis anterior; the electrode was placed 1/3 on the line between the tip of the fibula and the tip of the medial malleolus (SENIAM), the best location can be achieved in a sitting or supine position (Kleissen *et al.,* 1997), (see Appendix 20).

Soleus; The electrodes was placed 2/3 on the line between the medial condylis of the femur to the medial malleolus (SENIAM), (see Appendix 20).

All electrodes were placed by the GB and any loose wires were secured to minimise any *slip or trip* risk.

Accuracy of electrode placement and absence of cross-talk was confirmed by conducting pain-free lower limb movement against manual resistance provided by the GB whilst observing raw EMG waveforms for the following muscles:

Medial *Gastrocnemius* (MG) – resisted plantar flexion of the dominant kicking foot (raising on toes).

Tibialis anterior (TA) - resisted ankle dorsiflexion with inversion.

Soleus (S) participants were required to be in a seated positions and asked to raise their heels from the floor whilst restriction was applied.

Following the manual resistance testing of the SEMG the participants were then asked to perform maximal voluntary isometric contractions (MVIC) on their dominant kicking leg in order to enable normalisation of EMG to occur. Participants were instructed by GB of the procedure before they began the testing and were asked to remove shoes before testing so they would be barefooted when performing MVIC's. In order to perform MVIC's participants were seated on the Biodex chair and their dominant foot was strapped in to the leg attachment, using a cushioned placement for the foot and secured in place by a Velcro strap (see image 11). Once the foot was secured in place GB asked participants if they felt comfortable and also got them to dorsi flex the foot (bring the foot towards themselves) to ensure the strap was secure. GB then applied two straps going across the chest a belt going across the waist of the subjects, and one final strap going across the quadriceps of the dominant kicking leg (see image 12). This procedure was completed for all participants by GB, and participants gave verbal confirmation that the straps where tight. Participants were then instructed by GB that they were to perform five maximal contractions each lasting five seconds in duration with a ten second rest in-between. A traffic light symbol appeared on the computer monitor that

faced the participant to indicate when to begin the maximal contractions, as well as verbal instruction by the researcher of when to contract and when to rest.

MVIC's consisted of performing five repetitions lasting five second each of plantar flexion (pointing foot downwards) this was classed as the away movement (Medial Gastronomies and Soleus were activated during this movement). This movement was synchronised with the SEMG system. Once the participant had completed the five away repetitions they were given a 2 minute rest before they were asked to do another five repetitions with the same rest, only this time was the toward movements using dorsi flexion (bringing foot towards themselves in order to maximally contract the Tibialis Anterior). Again this followed the same procedure as the away movements in that subjects were asked to contract the muscles with maximum effort during all five repetitions. Throughout the MVIC's verbal encouragement was used by GB to gain maximal effort by the participants. MVIC's were only performed on the dominant kicking leg by the participants.

Once completed participants had a 2minute rest before performing the balance assessment. All effort was made by the GB to re-enforce the nature of the performing the MVIC's and to perform the repetitions at a maximal level and verbal encouragement was given throughout the testing to encourage participants to perform a 100% maximum contraction.

All contractions were completed in the same order for every participants in that all of the away contractions (plantar flexion) were completed first then following a 2 minute rest period the toward contractions (dorsi flexion) were performed.

Image 11: foot placement in Biodex Machine.
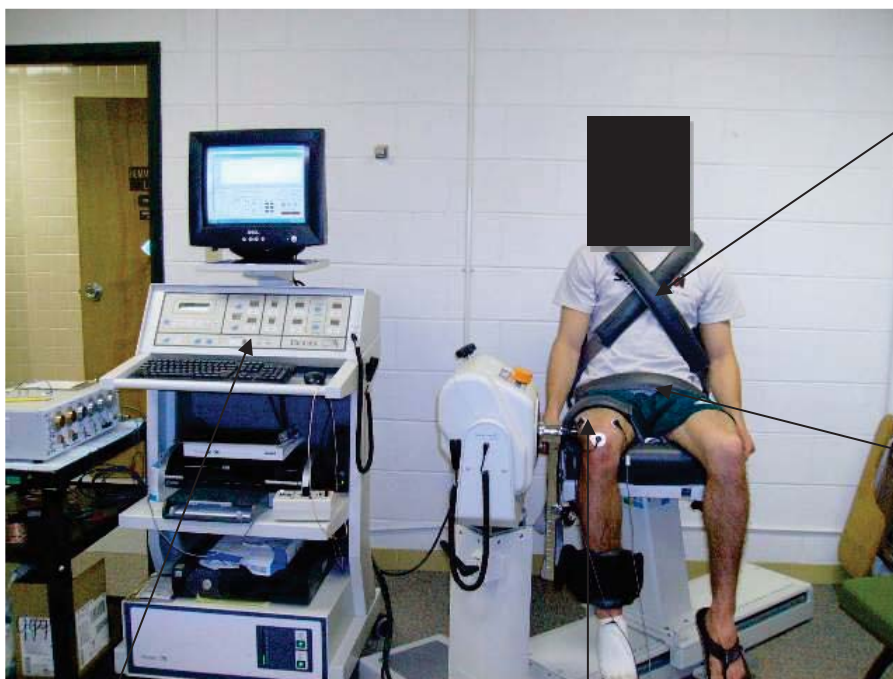
Chest straps

Waist strap

Biodex Computer

Leg Strap

Image 12: Biodex set up with chest, waist and leg strap in place.

9.21 Appendix 21: Conference Proceedings

External presentations and publications

Conference Proceedings

Barry, G., Van Schaik, P., MacSween, A., Dixon J., Martin D. (2011). An Investigation of User Acceptance and Flow Experience Using Video-Capture Gaming Technology for Exercise. IEEE proceedings *International Conference of Virtual Rehabilitation*, Zurich. (Oral presentation).

Barry, G., MacSween, A., Dixon J., Van Schaik, P., Dixon, S., Martin D. (2012). A Comparing the Effects of Exergaming and Mirror matched gym based exercise with no virtual stimuli on Balance in Healthy Sedentary Adults. Physiotherapy Research Society Conference, Sheffield, May 2012. (Oral presentation).

Barry, G., MacSween, A., Dixon J., Van Schaik, P., Martin D. (2012).The effects of Exergaming on Balance performance using the XBOX Kinect™. North East and Yorkshire Public Engagement Conference. York.

Publications

Barry, G., Van Schaik, P., MacSween, A., Dixon J., Martin D. (2012). Acceptance and Flow Experience in Virtual-reality-based Exergaming. Under review in Journal of Cyber Therapy and Rehabilitation.

An Investigation of User Acceptance and Flow Experience Using Video-Capture Gaming Technology for Exercise.

G Barry[1], P van-Shaik[2], A MacSween[1], J Dixon[1], D Martin[1].

1. School of Health and Social Care, Teesside University, Middlesbrough.
2. School of Social Science and Law, Teesside University, Middlesbrough.

INTORDUCTION: The increasing demand in technology can be seen in rehabilitation and health care. A recent development in rehabilitation research is exercising in a gaming environment incorporating virtual reality technology. This study investigated user perceptions of a video capture system for exercise (IREX™). The two main aims of the study were to compare the user acceptance of exercise using IREX™ with exercise in a gym-based environment; and to compare users' flow experience – absorption in the activity - using the two exercise environments.

METHODS: Ethical clearance was granted by Teesside University (TU) School of Health and Social Care Research Governance and Ethics Committee. Two questionnaires were used in this study. To assess participants' acceptance towards technology we used a questionnaire based on the *Unified Theory of Acceptance and Use of Technology (UTAUT)* [7]. The UTAUT has 22 questions which are sub-divided into; performance expectancy (PE), effort expectancy (EE), social influences (SI), facilitating conditions (FC), self- efficacy (SE) and behaviour intention (BI). The second questionnaire, the Flow State Scale [8], assessed participants' Flow experience. The Flow State Scale consists of a 36 items grouped in 9 sub-scales: Autotelic Experience (AE), Clear Goals (CG), Challenge-Skill Balance (CB), Concentration of Task (CT), Paradox of Control (PC), Unambiguous Feedback (UF), Action-Awareness Merging (AM), Transformation of Time (TT), and Loss of Self-Consciousness (LS).

All participants completed three exercise session lasting 30 minutes each. The sessions were conducted on a one-to-one basis in a university laboratory over a two week period. The questionnaires were completed pre exercise (baseline) and at the end (post-programme) of the two week programme.

RESULTS: Post-treatment there was a statistically significant difference between groups for PE (p=0.03), reflecting a within-subject increase from baseline to post-programme in the IREX™ group but not the gym-based group. No statistical significance was established for the remaining UTAUT variables between groups nor were any within-subject effects present.

Post-treatment there were no statistically significant differences between groups for Flow state scale (FSS).). Statistically significant within-subject changes over time were found for AE (p=0.01), CG (p=0.04) and TT (p<0.01), all of which showed an increase in both groups from baseline to post-programme. There were no interaction effects. There were no significant within-subject changes for the remaining Flow variable.

CONCLUSIONS: Both the IREX™ and mirror matched gym based exercise with no virtual stimuli were rated positively on the UTAUT subscales showing both to be useful and easy ways to perform exercise. Performance Expectancy was the only variable to demonstrate a significant difference: PE increased with the use of the IREX™, only. No other variables in the UTAUT showed any significant differences between groups. Neither environment was rated higher than the other for flow experience. The results show IREX™ as an acceptable alternative to mirror matched gym based exercise for this particular population.

A comparison of the effects of exergaming versus mirror matched gym based exercise with no virtual stimuli on postural control in healthy non-active adults.

G Barry[1], A MacSween[1], S Dixon[2], J Dixon[1], P van-Shaik[3], D Martin[1].

1. School of Health and Social Care, Teesside University, Middlesbrough.
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INTRODUCTION: Exergaming is the use of computer gaming technology and virtual reality environments for exercise is an option to encourage people to exercise. Exergaming has been used clinically with positive results [1-5]. As exergaming is still a novel approach, there is a shortage of good quality evidence of its effects on balance, an outcome of functional importance.

The aim of this study was to compare the effects of exergaming versus mirror matched gym based exercise with no virtual stimuli on postural control in young non-active adults.

METHODS: Ethical clearance was granted by Teesside University (TU) School of Health and Social Care Research Governance and Ethics Committee. We tested claims that exergaming is useful for improving balance in an experimental design with a convenience sample of healthy non-active participants randomised to one of two groups taking part in a two week programme of either exergaming (n=17) or mirror matched gym based exercise with no virtual stimuli (n=16). 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, and the CoP velocity during both unipedal and bipedal standing.

RESULTS: Analysis of covariance (ANCOVAs) comparing the post-intervention differences between the groups, with baseline values comprising the covariate where used. An alpha level of 0.05 was used throughout and 95% confidence intervals of the differences between the groups' post-intervention scores were calculated. Results showed statistically significant differences in the range ($p < 0.05$) and standard deviation ($p < 0.01$) of the anterior-posterior CoP excursion in unipedal standing between the exercise groups after intervention, with lower values in the exergaming group, indicating better postural stability.

CONCLUSION: The results show that exercising in an exergaming environment can be more beneficial for balance training than doing the same exercise without that environment.

Vitae Yorkshire and North East Public Engagement Competition and Conference,

Sheffield Children's festival on the 7th July 2012

G Barry[1], A MacSween[1], J Dixon[1], P van-Shaik[3], D Martin[1]

The effects of Exergaming on Balance performance using the XBOX Kinect™

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Exergaming

Exergaming is a combination of exercise and computer gaming and used to encourage people to exercise.

Specific claims have been made that exergaming has a particular role in improving balance in clinical conditions.

In a study of 17 healthy elderly adults Bateni [9] compared standard physical therapy with Nintendo Wii Fit™ balance based exercise and both of these in combination.

Balance is an important aspect of everyday living and should be incorporated into exercise regimes to help athletic ability and can be used to help postural alignment and control.

Balance is essential to all ages from the young development of motor skills to the elderly for the prevention of falls.

Balance can be easily measured through force platforms which give total movements (centre of pressure), Anterior- posterior movement (front and back) and medial- lateral (side to side) movements.