Understanding the Exergame User Experience: Users' Motivation, Attitude and Behaviour in a Location-Aware Pervasive Exergame for Adolescent Children

by

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Abstract of the Thesis

The benefits of physical activity for adolescent children are well understood. Despite this, within much of the Western World, children fail to achieve the recommended guidelines for physical activity participation, spending too much time on sedentary activities. Thanks to recent progressions in ubiquitous technologies, exergames - exercise video games - have emerged as a potential solution to the problem. By facilitating physical activity, and encouraging behavioural change within an enjoyable and motivating context, exergames have the potential to remove some of the barriers preventing many adolescents from sufficient physical activity participation. There are, however, few studies of exergame systems that have looked at the impact of the system over time. Additionally, many systems are not evaluated within ecologically valid contexts. The result of this is a lack of real understanding on the efficacy of exergame systems and their feasibility as a valid solution.

This thesis investigates the design, development, and evaluation of a location-aware exergame for adolescent children: iFitQuest. Through analysis of two prolonged use school-based evaluations, this research provides evidence on the ability of exergames to facilitate physical activity and reduce sedentary behaviour, when targeted at adolescent children within a school context. The results of two evaluations suggest that iFitQuest was enjoyable, motivating, and physically demanding, with the ability to promote physical activity of all intensities in players with a range of attitudes towards physical activity, their own physical activity abilities, and physical activity participation backgrounds. The primary contribution of this thesis is the in-depth evaluation of the exergame user experience. Looking beyond the general success of the system, the experience of individual players was analysed through the lens of Bandura's theory of self-efficacy. Through a mixed-methods case study analysis, self-efficacy was established as an accurate method to explain and understand in-game behaviour, in particular with respect to goal setting and game selection habits.

By influencing and moderating the players' motivation, attitude and in-game behaviour, self-efficacy was established as a useful tool for future exergame practitioners. Guidelines on the application of self-efficacy are provided, with respect to both analysis and design. Additionally, through a naturalistic and prolonged evaluation, a number of logistical and contextual lessons for the evaluation of exergames were established. In particular, the use of a user-centred design approach for the development of similar systems is validated through a series of design guidelines, which account for the importance and influence of the evaluation context.

To my family, without whom, none of this would have been possible.

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Glossary of Terms

AHPC

American Horsepower Challenge

DDR

Dance Dance Revolution

GM

Game Manager

MET

Metabolic Equivalent

mph

Miles Per Hour

MVPA

Moderate to Vigorous Physical Activity

NPC

Non-Player Character

PB

Personal Best

PA

Physical Activity

P.E.

Physical Education

RCT

Randomised Control Trial

RQ

Research Question

U-CD

User-Centred Design

WHO

The World Health Organisation

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CHAPTER 1

Introduction

Science now finds itself in paradoxical strife with society: admired but mistrusted; offering hope for the future but creating ambiguous choice; richly supported yet unable to fulfill all its promise; boasting remarkable advances but criticized for not serving more directly the goals of society.

J. Michael Bishop

The merits of physical activity are clear and well established. Despite this, throughout the developed world, children consistently fail to reach their physical activity targets, and instead choose to spend excess time performing sedentary activities. However, thanks to progressions in ubiquitous technology, a new potential solution has emerged in the form of exercise video games, *exergames*. By breaking down the barriers to traditional exercise, exergames have the potential to facilitate physical activity and promote behavioural change, within a fun and motivating context.

This thesis investigates the extent to which a location-aware pervasive exergame can be utilised within a school context to promote enjoyable and motivating physical activity for a group of adolescent children. It argues that when carefully designed, such an exergame can be effectively integrated into the school curriculum, in order to promote physical activity within an enjoyable context. Going beyond this, this thesis investigates in greater depth the exergame experience, in an attempt to better understand and explain the behaviour of the players. This thesis highlights important factors for consideration when developing and evaluating an exergame, through a list of design recommendations for future exergame developers, as well as logistical lessons learned through prolonged and in-situ evaluation. Crucially, this thesis argues that analysing player behaviour through the lens of self-efficacy theory provides valuable insight into the behaviour, attitude, and motivation of the players, with significant implications for future exergame practitioners.

This thesis describes iFitQuest, a location-aware pervasive exergame which was designed through an iterative, user-centred design process. By considering the related work in the field of exergames, as well as the opinion of players from the target demographic, Physical Education (P.E.) teachers and physical activity experts, iFitQuest was designed to be a physically demanding yet fun exergame, well suited to the constraints of a school context. iFitQuest was evaluated and validated through two principal evaluations, conducted in-situ within two disparate school contexts.

This chapter begins with an overview of the motivation for promoting physical activity in children, and the need for fresh approaches in achieving this. Exergames are then introduced, highlighting their potential as a solution, yet the need for further work in the field. The need to better understand the exergame experience is then discussed, motivating the use of self-efficacy in understanding the behaviour of the players. The main contributions of the work done within this thesis and the main research questions are summarised in Sections 1.4 and 1.5. An outline for the rest of this thesis is supplied in Section 1.6.

1.1 Children and Physical Activity

A key goal of recent guidelines issued by the Chief Medical Officers of the United Kingdom is to increase the amount of regular physical activity undertaken by children [51]. Across much of the developed world, the majority of children are failing to reach their physical activity guidelines [38, 44, 182, 214, 219]. Trends in adolescent behaviour have also shown increases in time spent on sedentary activities such as computer use and television viewing [148]. These two issues combined present a significant problem for children. Too little physical activity, and too much sedentary activity, are positively correlated with obesity [87, 92, 134] and negatively correlated with physical and cognitive development [188, 210], mental health [61, 126] and academic performance and behaviour [36, 57, 98]. There is thus clear motivation for increasing the amount of physical activity and decreasing the amount of sedentary activity performed by children.

There are a number of potential barriers preventing children from achieving the recommended physical activity guidelines [33, 47, 52, 154, 208, 215]. In particular, a lack of enjoyment in performing physical activity [53], a lack of interest in physical activity [208], a lack of physical activity options [27] and not having enough time [150, 208] represent commonly reoccurring barriers amongst children that could feasibly be addressed through successful physical activity interventions.

Thanks to progressions in ubiquitous technologies, a recent potential solution has emerged in the form of exergames. Video games that promote and encourage physical activity, exergames aim to harness the motivating and enjoyable nature of traditional video games, and combine this with the benefits of performing physical activity. By encouraging physical activity within such an environment, exergames have the potential to overcome the barriers to physical activity commonly identified by children.

1.2 The Potential of Exergames

While the genre remains in its infancy, exergame evaluations have begun to highlight the potential of such games to have a positive impact on the player. Studies have highlighted the ability of exergames to effectively facilitate physical activity [81, 108, 161, 225], improve players' aerobic fitness [145], and balance and lower limb strength [153]. Studies have also shown that exergames can be more enjoyable than traditional exercise [82].

While these studies have highlighted the potential of the genre, there exists a selection of literature highlighting the need for further work in the field of exergames. Studies have highlighted that when not carefully designed, exergames can fail to elicit improvements in the general well-being of the player [153], or help them reach their daily physical activity guidelines [83]. Additionally, a novelty effect has been observed, whereby once interest in the game decreases, so too does the player's motivation to remain physically active [115, 131, 163, 204, 229]. Furthermore, there is a lack of ecologically valid results with respect to prolonged usage of a system, with the majority of exergames evaluated as part of short term, or lab-based evaluations, which fail to consider the implications of prolonged use, or the system's context. Such findings raise questions about the suitability of exergames to elicit long term improvements to the health of the player, and their feasibility as an answer to the aforementioned issues with respect to children and physical ability.

There is thus a need for further investigation into the potential of exergames. In particular, for fully valid results, exergames must be evaluated in-situ and over a prolonged period of time, rather than single usage or lab-based evaluations. Further to this, exergames targeted specifically towards children, and for use within a school-based context, are not heavily explored within the field of exergames. This thesis aims to close this gap in the knowledge, through the development of a system for an adolescent demographic, deployed and evaluated over a prolonged period of time within school context.

The work done within this thesis focuses on a particular style of exergame, known as *pervasive exergames*. Such games aim to break play out into the real world of the player, allowing for play to be conducted within a wider array of spaces, in contrast to the constraints of a console exergame, for more socially rich experiences, in which a greater type and variety of physical activity can be facilitated.

1.3 Understanding the Exergame Experience

Going beyond the general success of a system, there also exists motivation to better understand the exergame experience. While many practitioners have identified the successes, or failures, of the genre, few have begun trying to better understand the experience of the players. Understanding exactly why, or why not, an exergame was a success, and the influential factors over the experience, would provide insight into how to better design and develop effective exergames in the future. Such knowledge could prove invaluable to exergame practitioners wishing to develop optimally effective experiences, with the goal of validating exergames as a successful means to promote physical activity.

Exergame practitioners have begun looking at various elements of the exergame experience. Virtual incentives [23], social awareness and peer support [211], competition [115, 230], collaboration [230] and single versus multiplayer exergames [158] have all been investigated and the merits of each discussed.

This thesis aims to understand the exergame experience by analysing data through the lens of *self-efficacy*. Bandura's work on self-efficacy plays an important role in aiding in the understanding of motivation. Bandura writes, "Self-Efficacy is concerned with judgments of how well one can execute courses of action required to deal with prospective situations" [11, p.122]. In other words, a person's self-efficacy is their level of belief that they can perform adequately at a given task. A person's self-efficacy for a task is based upon 1) past performances on said task; 2) vicarious information; 3) persuasive information (such as social influence); and 4) arousal information based upon physiological cues [12].

Self-efficacy can play an important role with respect to physical activity. In their review on the role of self-efficacy within health behaviour change, Strecher et al. found that "self-efficacy appears to be a consistent predictor of short and long term success" [201, p.87]. Furthermore, within the context of physical activity participation, Dzewaltowski et al. found that Bandura's social cognitive theory variables, including self-efficacy, significantly predicted physical activity participation [58]. Exergame interventions with a view of sustaining physical activity behavioural change should thus not only consider the pre-intervention self-efficacy of the participants, but also set about increasing and / or maintaining the participant's self-efficacy with a view of facilitating long term behavioural change.

However, going beyond this, self-efficacy is also of relevance when trying to better understand the exergame experience. Bandura states, "Self-Efficacy beliefs contribute to motivation in several ways; they determine the goals people set themselves, how much effort they expend, how long they persevere in the face of difficulties, and their resilience to failures" [15, p.131]. Bandura's theories on self-efficacy are a key indicator of how participants will react to self-set and assigned goals [4, 8, 22], as well as how hard they will push themselves in order to meet goals, and how they will react when faced with problems and / or failures. Practitioners wishing to understand the behaviour of an exergame player, and the reason behind certain decisions and changes in attitude, should consider the self-efficacy of that participant as a potential moderator of, and influential factor on, their actions.

Practitioners have begun to investigate self-efficacy within the context of exergames. In their work on promoting self-efficacy with an exergame, Song et al. investigated the way people of different self-efficacy profiles reacted to the image of their own body on screen [192]. Meanwhile, Staiano et al. found that cooperative play of Wii Active increased the self-efficacy of the players [194].

The related work on the theory of self-efficacy highlights its potential to not only predict the success of a physical activity intervention, but also the way people will behave during an intervention, in terms of their motivation and attitude. The way one's self-efficacy manifests itself within their in-game behaviour, and its influence on the exergame experience, is an area that requires further investigation. Understanding the influence of self-efficacy on the exergame experience, and the resultant implications for exergame practitioners is one of the central avenues of investigation within this thesis.

1.4 Summary of Contributions

The primary contributions of the work done within this thesis can be summarised as follows:

- *A location-aware exergame, iFitQuest, was developed and evaluated within a school-based context with children from an adolescent demographic.* The results of two prolonged evaluations extends the body of knowledge on the suitability of exergames for adolescent children, the suitability of exergames for school contexts, and the suitability of location-aware pervasive technology for exergames. In particular, the way in which this type of system can promote a range of physical activity intensities and support children from a variety of backgrounds was evaluated and validated.

- *iFitQuest was evaluated through the lens of self-efficacy in order to better understand the exergame experience.* The way in which self-efficacy was effectively utilised to understand and explain the behaviour of iFitQuest players outlines that self-efficacy can prove to be a valuable construct when designing and evaluating exergame system. The methodology adopted within this thesis extends the understanding of how to effectively evaluate exergame systems.

- *Through the development and evaluation of iFitQuest, a number of important design recommendations were established.* Through an iterative and user-centred design philosophy, as well as the school-based evaluation of iFitQuest, a number of design guidelines and recommendations were established and validated. The work within this thesis extends the literature on designing exergames by further validating previously outlined recommendations as well as adding additional guidelines, particularly well suited to exergames for adolescent children and school contexts.

- *A concise review of health and fitness and exergame literature.* A further contribution of this thesis is the concise literature reviews presented within Chapter Two and Chapter Three, which serve to highlight not only the potential of exergames for promoting physical activity, but also the gaps in the literature which the work done within this thesis aims to close.

A full and more detailed list of the contributions and findings of this thesis are outlined within Chapter Ten.

1.5 Main Research Questions

This thesis describes the design, development and evaluation of a location-aware exergame titled iFitQuest. The primary research questions for the thesis are as follows:

RQ 1. To what extent can a location-aware exergame played within a school-based context promote physical activity, while remaining enjoyable and motivating?

RQ 2. Which features and elements of iFitQuest contributed towards the exergame experience of the participants, and the overall success of the system?

RQ 3. To what extent can self-efficacy be utilised to understand and explain the exergame experience?

During the two primary iFitQuest evaluations (outlined in Chapter Six and Chapter Seven) these research questions are broken down into a series of sub-questions. Full detail on how each sub-questions relates to the three primary research questions, and the data sources / analysis techniques that are used to answer these questions, is outlined in Appendix G.

With RQ 1. dealing with the design, development and evaluation of an exergame, it is important to define what represents *success*. As will be outlined within Chapter Three, the primary goal of an exergame is to promote physical activity within an enjoyable and motivating context. Thus, the exergame developed for this thesis has the goal of facilitating physical activity while remaining motivating and enjoyable to the players. Additionally. the exergame is designed to promote not only physical activity, but moderate to vigorous physical activity while also preventing sedentary behaviour, the importance of which is discussed within Chapter Two. As is discussed within Chapter Three, many exergames have the goal of influencing the long term behaviour of the players. Thus, a further facet of investigation within this thesis is to provisionally investigate whether the behaviour or attitude of players can be influenced by playing iFitQuest.

RQ 2. and RQ 3. aim to look in greater depth at the exergame experience. In complement to RQ 1, these research questions are designed to ask not only *if* the exergame is successful at promoting enjoyable and motivating physical activity, but also *how* and *why* it is, or is not, successful. By using theories from behavioural psychology, the goal is to fully understand the contributing factors which influence the exergame experience, in the process contributing to the field of exergame knowledge by providing guidance on how to better design and evaluate exergames.

The goals of this thesis can therefore be summarised in two general stages: 1) design and develop a successful exergame, in the process investigating the merits of location-aware pervasive exergames, exergames for adolescents, and exergames for a school context; 2) with a successful exergame to evaluate, use theories from behavioural psychology to better understand the exergame experience, in particular how the behaviour, attitude and enjoyment experienced by a player can be influenced by the player's background, the design of the exergame itself, and the context of the evaluation.

1.6 Thesis Outline

This thesis is organised into ten chapters and seven appendices.

Chapter Two discusses the relevant physical activity and behavioural psychology literature, which underpins much of the motivation for this work. The chapter begins with a justification for physical activity interventions, outlining the benefits of regularly performing physical activity, and the risks of a sedentary lifestyle, with particular reference to adolescent children. Following this, a number of prominent examples of physical activity interventions are discussed, providing justification for the context adopted for the evaluations of this thesis, the length of studies undertaken, and the type of results to be expected. The chapter then moves on to discuss in depth Bandura's work on self-efficacy and why it is of relevance to a physical activity intervention, justifying it as the concept which underpins Research Question 3 of this thesis.

Following this, Chapter Three introduces exergames. The chapter begins by explaining the genre of exergames, outlining the various forms they come in and subgenres that exist. The justification for evaluating exergames as a potential method to facilitate physical activity is outlined. Related work which highlights the benefits of exergames, in particular for an adolescent demographic is presented and discussed. The chapter also highlights the specific sub-genre most relevant to this thesis, pervasive exergames, by discussing the related work in the field, and relative successes that motivated the adoption of the genre for this thesis. Finally, the chapter concludes with a discussion of exergame design requirements, outlining those adopted for iFitQuest.

Having introduced the motivation for iFitQuest, Chapter Four discusses the design and development of the system. The chapter begins with an overview of the methodology adopted for the development, an iterative prototype driven user-centred design approach, and the primary development phases that this included. Each primary phase is then discussed in depth. For each phase, an overview of the work done, and the findings that influenced each subsequent phase are highlighted. Particular attention is paid towards the latter two stages, where high-fidelity prototypes were developed and evaluated as part of small scale empirical studies.

Following the overview of the development process, Chapter Five provides an overview of the final iFitQuest system. The chapter begins by presenting the final changes made to the system, as a consequence of the second prototype evaluation discussed at the end of Chapter Four. An overview of the final system is then given, providing an in-depth conspectus of the finer technical details; such as the hardware and software adopted for the system, and the final system architecture. The chapter concludes by outlining the design guidelines adopted for the development (established throughout Chapter Four), highlighting how each guideline has been satisfied within the final iFitQuest system.

Chapter Six and Chapter Seven detail the two principal empirical iFitQuest evaluations, designed to answer the research questions of this thesis. Chapter Six focuses on the first evaluation, a 5-week study conducted within a high school P.E. class, during which 14 children aged between 14 and 15 years old played iFitQuest. Chapter Seven then focuses on the second evaluation, a 7-week study conducted within a more flexible primary school context, during which time 12 children aged between 11 and 12 years old played iFitQuest between one and three times per week. Each chapter follows the same format. First, the purpose of the evaluation is discussed, along with an overview of the method, containing details of the data gathering techniques, participants, school profile and procedure. The results of the evaluation are then presented, moving from the general overview through key areas related to this thesis, such as the *physical activity* facilitated, *motivation* of the players, *novelty effects*, and *participant changes*. The results section of each chapter concludes with a series of case studies. Constructed using mixed methods analysis on the various streams of data, the case studies provide the greatest insight into the emergent behaviours of the players and serve to answer Research Question 2 and 3. Each chapter then concludes with a brief discussion of the results and a summary of the findings.

The primary discussion is saved for Chapter Eight. By considering the results of both principal evaluations, Chapter Eight discussed in depth the research questions posed in Section 1.5 and highlights the primary contributions and findings of this thesis. The chapter begins with a high-level discussion on the success of iFitQuest as a method of facilitating physical activity within an enjoyable and motivating context. Following this, the effectiveness of adopting the school as a context is discussed, by highlighting the various ways it impacted upon the evaluation of FitQuest. The discussion then moves onto a more in-depth analysis of the exergame experience. Self-efficacy and its impact on the exergame experience is discussed by highlighting the various interesting ways it impacted upon the iFitQuest evaluations. Based on this, a list of implications and considerations for future exergame developers and evaluators is provided. The design requirements outlined in Chapter Five are then revisited and validated with a discussion on how they impacted upon the success of iFitQuest, and how they could be used by future exergame practitioners. The chapter concludes with a discussion of the logistical lessons learned throughout the development and evaluation process, providing further advice to future exergame practitioners on the specific successes and failures of the process adopted for this thesis.

Chapter Nine describes ongoing and future work. First, the chapter outlines currently ongoing work, in particular further analysis of the data gathered during the two principal iFitQuest evaluations, which was not of direct relevance to the topics of this thesis. Future empirical work is then discussed, highlighting the ways in which the findings and contributions of this thesis can be further validated and extended upon. Based on the results outlined within Chapter Six and Seven, future development work to improve the iFitQuest system is then suggested, as a means to increase its effectiveness moving on to the future evaluations.

Finally, the thesis concludes with Chapter Ten, a summary of the primary contributions and findings of this thesis, related back to the initial research questions presented within Section 1.5 of this chapter.

CHAPTER 2

Physical Activity and Children

In 2011, the UK governments Chief Medical Officers released for the first time a set of UK-wide physical activity guidelines. The purpose of the document was to highlight the recommended amount of physical activity a person should achieve, and the means by which the guidelines could be met. The Chief Medical Officers write, “This report emphasises for the first time the importance of physical activity for people of all ages” [51, p.6]. Similarly, the World Health Organisation (WHO) published their own set of physical activity guidelines, after seeing physical inactivity levels rising in many countries [227]. The importance of physical activity, particularly in children, has never been better understood and higher on the public health agenda.

With this thesis focussing on the development of an exergame, designed to aid adolescent children in achieving their physical activity targets, it is important to begin by establishing exactly what physical activity is, why it is important that children meet the physical activity guidelines, and what methods can be used to help children along towards their goals.

This chapter begins by establishing what constitutes physical activity and the motivation for promoting physical activity in children. With that established, the chapter explores the different ways physical activity can be facilitated within an adolescent demographic, aiding in the understanding of why certain iFitQuest design decisions were made. Following this, self-efficacy is explored as an important psychological construct within physical activity interventions. The role self-efficacy plays on the success of physical activity interventions, and the behaviour of participants within those interventions, is discussed, motivating the use of self-efficacy as a tool to understand the exergame experience.

2.1 Children and Physical Activity

The WHO define physical activity as “any bodily movement produced by skeletal muscles that requires energy expenditure” [228]. More simply, the United States Department of Health and Human Services defines it as "bodily movement that enhances health" [218, p.2]. In other words, it encapsulates any movement that requires the body to work harder than it would while completely at rest.

Physical activity can be categorised based on the intensity of the activity, generally into *light*, *moderate*, and *vigorous*.

Table 2.1 illustrates some examples of physically demanding activities, and the intensity of physical activity they generally produce. The table is adapted from Ainsworth et al's. *Compendiums of Physical Activities* [1], and the understanding of how Metabolic Equivalent (MET) (a physiological measure of energy expenditure) can be translated to physical activity intensity [69].

Activity	**METs**	**Intensity**
Ironing / Putting away clothes	2.3	Light
Horse Riding (Walking)	2.5	Light
Walking with children	2.5	Light
Mopping floor	3.5	Moderate
Cycling to school / work	4.0	Moderate
Ballet or tap dancing	4.8	Moderate
Calisthenics (e.g. pushups / situps)	8.0	Vigorous
Running (5 mph +)	8.0 - 18.0	Vigorous
Football	10.0	Vigorous
Swimming (Fast laps)	10.0	Vigorous

Table 2.1: Common activities distinguished by intensity of physical activity facilitated.

While it is generally understood that some exercise is better than no exercise at all [26], the relevance of activity intensity comes from the fact that children (aged 5 - 18 years old) are encouraged to achieve 60 minutes of *moderate to vigorous* intensity physical activity every day [51]. The justification for this is outlined within Section 2.2.

In much of the developed world, children are failing to reach these physical activity guidelines. In England, only 33% of 11 year old boys and 20% of 11 year old girls achieve the recommended levels of physical activity [44], with similar trends for children in the USA [214], Canada [38] and across Europe [219]. The Scottish Health Survey states that 73% of Scottish children (aged between 2-15 years old) reach their physical activity targets [182], although this is based on self-reporting questionnaires and as such must be interpreted with caution [104, 186]. Even if the results are accurate, the figure still falls short of the Scottish Governments target of having 80% of children under 16 years old meeting the current recommended levels of physical activity.

While improvements could be seen for all children, there are particular demographics that fall short with regards to physical activity. The Scottish Health Survey 2011 highlights that the percentage of 13-15 year olds reaching their physical activity targets is considerable lower than across the rest of the childhood age ranges [182]. This is consistent with what is known as the 'adolescent slump', whereby children aged 11 or 12 years old generally show a downturn in physical activity participation [43, 172]. In general, girls are less likely to achieve the recommended physical activity guidelines than boys [38, 182, 214, 219]. Ethnic differences have also been observed [79], with socioeconomic factors also influencing physical activity participation [80].

2.2 The Importance of Physical Activity

With clear evidence that children are falling short of achieving the recommended levels of physical activity, it is important to understand the impact low levels of physical activity can have on one's health.

Physical inactivity has been identified as the fourth leading risk factor for global mortality, accounting for 6% of deaths globally [226]. The reason for this can be in part attributed to the fact that staying physically active is linked to a reduction in the risk of developing coronary heart disease [25], cardiovascular disease [221] and some cancers [70, 77, 221]. Physical activity and obesity are also closely correlated [87, 92], with obesity itself carrying a number of risk factors including type 2 diabetes and abnormalities of the heart [106].

Engaging in physical activity during childhood has been linked to both physical [188] and cognitive development [210], with physical activity positively correlated with happiness and self-esteem [61, 126] and academic performance and behaviour [36, 57, 98]. Additionally, being physically active and fit during childhood has been identified as a predictor of adult activity levels [50, 209].

Physical activity guidelines for children recommend at least 60 minutes of *Moderate to Vigorous Physical Activity (MVPA)*. Practitioners have looked at exercise intensity and found that to derive the greatest health benefits, MVPA should be targeted [202]. Studies have shown a decline in childhood MVPA is associated with a greater increase in fat mass index in boys [20], and that higher intensity exercise is more suitable for targeting the obesity epidemic [198]. MVPA has also been shown to improve insulin sensitivity (a risk factor for type 2 diabetes) [62]. In addition, vigorous intensity exercise has been shown to produce greater cardioprotective benefits, such as aerobic control and lowering diastolic blood pressure [206]. Additionally, higher intensities of physical activity training have been shown to elicit the most effective improvements to cardiorespiratory fitness [205].

A number of common childhood activities, along with their respective intensity of exercise facilitated, is shown in Table. 2.2.

Activity	**METs**	**Intensity**
Sleeping	0.9	Sedentary
Watching T.V.	1.2	Sedentary
Reading (sitting)	1.3	Sedentary
Pool/Billiards/Snooker	2.5	Light
Paper round (long period of walking)	2.9	Light
Playing with animals / younger children (walk/run)	2.8-5.0	Light to Mod.
Gymnastics	3.0-5.0	Moderate
Hide & Seek	4.0	Moderate
Tig / Tag	3.8-6.3	Mod. to Vig.
Hopscotch	4.4-7.4	Mod. to Vig.
Football	6.6-11.0	Vigorous
Climbing trees	8.0	Vigorous

Table 2.2: Common children's activities with associated intensity of physical activity facilitated, from [170].

As well as achieving one hour of MVPA per day, children should be encouraged to minimise the amount of time they spend undertaking sedentary activities. As stated, physical inactivity is the fourth leading risk factor for global mortality [226], with a reduction in sedentary behaviour associated with lower health risks in children [213]. Longitudinal evaluation has shown an increased prevalence of sedentary activities in adolescence, in particular leisure time computer use [148, 219]. Practitioners have thus called for health promotion strategies that address both MVPA and sedentary activity [148, 219], with one suggested approach to convert leisure screen time to active screen time [109].

To summarise, physical activity during childhood is important to both physical and mental well-being, in both the short term and long into adulthood. While all physical activity is beneficial, guidelines specify that children should achieve 60 minutes of MVPA per day. To this end, any exergame system should have the general aim of facilitating physical activity (and thus preventing sedentary activity), but the additional aim of MVPA. Thus, any use of the system would contribute towards the players' physical activity targets and has the potential to elicit the greatest long term health benefits. An exergame that facilitates only light intensity exercise would however still elicit health and fitness benefits, especially if the exergame was being played instead of a sedentary activity like traditional video game play.

2.3 Facilitating Physical Activity

With the health benefits of physical activity established, it is important to consider *why* children are generally not meeting their physical activity guidelines.

Reasons include *ecological determinants*, with access to recreational facilities and transport positively associated with physical activity participation [47, 215]. Neighbourhood safety and parental anxiety are also reasons why children are spending less time outdoors being physically active and more time inside participating in sedentary activities [33].

Psychological considerations include exercise self-efficacy [52, 215], attitude towards physical activity [215] and enjoyment of physical activity [53]. People with positive attitudes towards physical activity, who enjoy participating in physical activity, and have confidence in their ability levels, are more likely to participate in physical activity than those who do not.

Amongst the other common reasons for a lack of physical activity participation, time constraints is a regularly identified barrier, in particular with girls [150, 208]. Additionally for girls, support from peers, parents and teachers is a consistent factor associated with changes in physical activity [150]. How physically active their parents are [154], a lack of interest [208], and unsuitable weather [208] are also identified as barriers to physical activity in adolescents. Bocarro et al. argue that the decline in sporting participation amongst children is partly related to there being fewer options provided, in particular to those less talented and thus less eligible for extracurricular sports teams [27].

It is impossible for a physical activity intervention to target all factors and barriers. However, there is evidence to suggest the physical activity interventions can work. In their comprehensive review, van Sluijs et al. found that interventions can increase the physical activity of the participants [189]. Similarly, Kriemler et al. found school-based physical activity programmes can effectively improve fitness and reduce adiposity [107]. van Sluijs et al. provide a detailed overview of the variety in characteristics of a physical activity intervention. Examples include the addition of more P.E. classes, additional sport-based after school clubs, and focussed skill based physical activity training [189]. Evidence suggests that while numerous factors can influence one's physical activity participation, a well designed and executed physical activity intervention can effectively raise the participants' physical activity levels and facilitate the associated health benefits.

2.4 Physical Activity and the Intervention Context

An important and fundamental decision when designing any (including exergame based) physical activity intervention is deciding the context in which the intervention should take place. Prior research has shown that understanding the context of a health promotion program (e.g. schools, homes or communities) is essential to its successful design and implementation [46, 105, 127, 199]. With regards to children, there are a number of feasible options. Physical activity interventions can be school-based, extra curricular (e.g. after school clubs and Boy Scouts), home-based, or indeed across multiple contexts.

While there exists evidence for home-based [177], extra curricular [21] and cross-context [189] interventions, it was decided that iFitQuest should be designed for a school-based intervention.

As Wechsler et al. state, "School opportunities for participation in physical activity include physical education classes, recess periods, extracurricular sports and physical activity programs, and access to school gymnasiums, playing fields and, playgrounds. Schools also have personnel who, with sufficient training and commitment, can design and deliver effective nutrition and physical activity programs, establish and enforce policies that support healthy choices, and serve as powerful role models for students." [223].

School-based physical activity interventions have enjoyed relative success. In a longitudinal two-year intervention, Sallis et al. found that a P.E. based intervention could be of benefit to 97% of the population from their target group [179]. McMurray et al. found that increasing both the aerobic aspects of P.E. and educating adolescents on weight control helped improve blood pressure and Max VO_2 [128]. Pate et al. [157] and Sallis et al. [178] provide further evidence on the effectiveness of school-based physical activity interventions.

Further to this, within the exergame literature there exists positive tentative research on the merits of deploying exergames within school-contexts. The AHPC, an inter-scholastic pervasive exergame successfully encouraged school children to walk more [163]. In a small scale study, Fogel et al. found that exergames provided both more opportunity for physical activity, and more actual physical activity than a standard P.E. program [67]. Staiano and Calvert provide a summary of the physical, social and cognitive benefits of deploying exergames within P.E. courses [195]. Full details of the related work with respect to exergames is outlined in Chapter Three.

The literature highlights the merits of both general and exergame school-based physical activity interventions. There are also a number of logistical benefits to developers when adopting this context. First of all, children are legally obliged to attend schools and as such, schools provide the best access to the demographic. Extracurricular physical activity interventions have suffered from poor attendance [91] and also penalise those who cannot attend. Another factor is that of control. A home-based intervention could suffer from a number of confounding factors which would influence the individual's exergame experience [177]. By choosing a school-based intervention, it is possible to exert greater control on the environment, ensuring that each participant has a level playing field for the experience and helping to ensure ecological validity in the results. Finally, from a logistical point of view, a school-based environment helps with the control of equipment and allows for observations to be included within the experimental design.

To summarise, selecting the context of a physical activity intervention is an important decision which can affect the outcome of a trial. While there exists evidence supporting other contexts, a school-based intervention was the logical choice for this thesis, due to the plethora of positive evidence advocating such an approach, for both traditional and exergame interventions, as well as the additional control it allows and pragmatic benefits it provides.

2.5 Physical Activity and iFitQuest: Intervention Length

While it is clear that physical activity interventions can effectively target children, it is important to consider the design of such interventions, with respect to length and frequency of use. Such investigation aided in the design of the iFitQuest evaluation, as well as predicting the potential impact iFitQuest could have.

Sluijs et al. provide a review of controlled trials which aimed at facilitating physical activity amongst adolescent children. Through their systematic review, they identified 57 relevant studies. Their results showed that effective interventions successfully increased the participants' physical activity from anywhere between 2.6 minutes to 283 minutes per week. While this represents a wide range, it highlights that for a physical activity intervention to be successful, any increase in physical activity participation is viewed positively. Of the 57 trials highlighted in their review, length of study varied from single educational sessions to 6 year longitudinal interventions. Four studies were 4-weeks long, two were 5-weeks long, one was 7-weeks long, one was 8-weeks long, and two were 9-weeks long; fourteen studies were between 10-weeks and 16-weeks. The number of sessions per week differed based on the type of intervention, as many were multifaceted and contained educational aspects such as doctors consultations, and lectures, as well as physical activity facilitation. Physical activity sessions generally occurred between one and three times per week, lasting between 20 minutes and two hours [189]. In a similar study, Dobbins et al. reviewed 26 interventions. While a range of intervention lengths were again considered, the paper highlights that longer school-based evaluations are generally more successful than shorter studies [54].

With respect to behaviour change and attitude, Prochaska et al. discuss the fact that any observed behaviour changes must be maintained for several years before they can be considered [164]. As this is outwith the scope of the work within this thesis, any influence iFitQuest has on the attitude of the participants, while still of interest and of consequence, must be interpreted with caution.

The literature highlights that while prolonged and regular intervention sessions would elicit the greatest chance of facilitating physical activity, small changes can be expected from single session or short term studies. Thus, any physical activity facilitated by iFitQuest can be viewed as successful. In terms of behavioural change, and alterations in attitude, changes could be facilitated although are unexpected outwith longitudinal evaluation, and any observed changes must be interpreted with caution. Within the methodology sections of Chapter Six and Chapter Seven, the length of each evaluation is justified with reference to the work presented within this chapter, as well as the length of similar exergame evaluations, presented within Chapter Three.

2.6 Physical Activity: A Summary

In the chapter thus far, the importance of physical activity for children has been established, through a review of the various health and well-being benefits achieved through meeting physical activity guidelines. The various barriers preventing children from achieving their physical activity guidelines have been discussed, along with the importance of the context adopted for a physical activity intervention. At this stage it should be clear why addressing childhood physical activity participation is of particular importance. In the remainder of this chapter, the role of *self-efficacy* within physical activity is discussed, as this is of particular importance to the research questions adopted for this thesis.

2.7 The Role of Self-Efficacy in Physical Activity

Earlier in this chapter, barriers preventing children from participating in physical activity were discussed. At a general level, it is important to consider the notion of *motivation*. When a person is provided with an opportunity to do something, but choses not to, they can be characterised as unmotivated. "A person who feels no impetus or inspiration to act is thus characterized as unmotivated, whereas someone who is energized or activated towards an end is considered motivated" [176, p.54]. While barriers such as a lack of time, or opportunities can be addressed by providing a physical activity intervention, ensuring the children are motivated to participate is a more complex issue, which requires a deeper understanding of motivational theories.

As Ryan and Deci state, "Although motivation is often treated as a singular construct, even superficial reflection suggests that people are moved to act by very different types of factors, with highly varied experiences and consequences" [175, p.69]. One commonly accepted theory is that one's motivation can be categorised as *intrinsic* or *extrinsic*. Ryan and Deci explain, "intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome" [176].

In a similar vein, Nicholls discusses one's motivation towards being successful and demonstrating ability within a particular task. He differentiates again between two contrasting approaches; *task-involved* and *ego-involved*. In task-involvement, improvement is the goal, one gets motivation through a desire to improve and seeing themselves master a task. Conversely, ego-involved individuals seek to perform solely to boost their ego, be it through praise or winning in competitions [152].

One important consideration when understanding motivation is the notion of self-efficacy. In Section 2.3, when discussing barriers towards physical activity participation, self-efficacy was highlighted as a commonly identified factor [52, 215]. Bandura describes self-efficacy, stating, "Self-efficacy is concerned with judgments of how well one can execute courses of action required to deal with prospective situations" [11, p.122]. Further, Bandura states, that "Efficacy beliefs influence how people feel, think, motivate themselves and behave" [15, p.118]. In other words, a person's self-efficacy is their level of belief that they can perform adequately at a given task.

Self-efficacy is not a constant, but rather a variable that can be influenced. Bandura writes that an individual's self-efficacy towards a task is based upon: *a*) past performances on said task; *b*) vicarious information; *c*) persuasive information (such as social influence); and *d*) arousal information based upon physiological cues [12]. It is important to note that self-efficacy is task specific; someone may have high math self-efficacy, yet low exercise self-efficacy [13].

Self-efficacy has been found to play an important role in understanding and promoting health behaviour. In their review on the role of self-efficacy within health behaviour change, Strecher et al. found that "self-efficacy appears to be a consistent predictor of short and long term success" [201, p.87]. Strecher et al. looked at the role of self-efficacy within various health behaviour domains, including alcohol abuse, giving up smoking, weight loss and exercise. Furthermore, within the context of physical activity participation, Dzewaltowski et al. found Bandura's social cognitive theory variables (including self-efficacy) significantly predicted physical activity participation [58]. In children and adolescents, higher self-efficacy levels have been positively correlated with more intense physical activity [150, 200]. Self-efficacy has also been known to influence the amount of enjoyment experienced during physical activity [89].

As well as predicting the success of a physical activity intervention, and the level of physical activity performed by the participants, self-efficacy has been shown to influence and moderate the behaviour of those taking part in physical activity.

Bandura has shown that the stronger the perceived self-efficacy, the higher the goal challenges people set for themselves and the stronger their commitment is to achieving these goals [14]. In other words, when faced with a task, a participant with high levels of self-efficacy is more likely to set themselves a high and challenging goal, than those with low levels of self-efficacy. Additionally, those with high self-efficacy are more likely to remain committed to achieving said goals. Goal setting is an important concept within motivation theory, with studies showing that the adoption of goals is more likely to maintain one's commitment towards a task, and performance within a task, both important constructs for physical activity and exergame interventions [116, 117, 119].

Self-efficacy not only influences reactions to self-set goals, but also assigned goals [110, 117, 119]. Those with a higher self-efficacy are more likely to adopt further challenges for themselves [15], and are known to "exert greater effort when they fail to master the challenge" [15, p.131]. It has thus been well established that one's self-efficacy can not only determine the goals one is likely to set themselves, the way they react to assigned goals, but also what behaviour they exhibit when goals are achieved or failed. Bandura writes, "Adopting further challenges creates new motivating discrepancies" [15, p.132]. Those with high levels of self-efficacy actively seek discrepancy between performance and goal, as a means to provide motivation. So while someone with high self-efficacy may become more motivated when a goal is missed (and thus a discrepancy is produced), those with a low self-efficacy are likely to show avoidance due to a lack of goal commitment. The implications of goal setting within an exergame physical activity intervention comes from the importance of challenging goals to enhance motivation and performance attainment [116, 119, 130], although there remains some doubt on its effectiveness with an adolescent audience [184].

As well as having influence over goal setting behaviour, an individual's level of self-efficacy also influences how they interpret failure. Someone with a low self-efficacy is more likely to blame their own lack of ability, as opposed to those with higher levels of self-efficacy who will attribute shortcomings to an 'off-day' or bad luck [15]. Those with high levels of self-efficacy may also react poorly when they cannot exert control over their environment, and the outcome of a task is negative. If someone has a high belief in their ability, when there is a negative outcome, if said person believes that despite their abilities it is not possible to control the outcome, it can lead to resentment and protest [8, 11].

Self-efficacy also plays an important role within the type of motivation elicited from an activity. Within the context of self-regulated learning, Bandura and Schunk found that perceived self-efficacy was positively related to intrinsic interest in the subject being taught [19]. Zimmerman and Kitsantas found the same for tasks involving motor skills; self-efficacy highly correlates with intrinsic interest [236].

To summarise, self-efficacy plays a key role in not only predicting the success of a physical activity intervention, but also the behaviour of those taking part during the intervention. With this in mind, exergame interventions with a view of sustaining behavioural change should thus not only consider the pre-intervention self-efficacy of the participants, but also set about increasing and / or maintaining the participants' self-efficacy with a view of facilitating long term behavioural change.

Within this section, evidence to support the use of self-efficacy as an important construct for understanding and promoting physical activity participation has been outlined. However, it is important to consider the scope of self-efficacy and how it fits within the greater field of health behaviour theories. As Hekler et al. outline, behaviour theories exist on a continuum from general to specific. At one end, there exists meta-models, which are organisational structures of multiple levels of influence on an individuals behaviour. At the other end, are the highly specific empirical findings, which exist where previously developed theories are insufficient to guide research. Self-efficacy, as a construct, exists towards the specific end of the spectrum. The benefit of focussing on specific constructs rather than entire frameworks is that constructs allow for a smaller and more specific level of analysis as well as translating more easily into features of a behaviour change technology [85]. However, researchers focussing on specific constructs run the risk of ignoring influential factors that lie outwith the scope of investigation, or returning misleading results when constructs are not properly evaluated with consideration of the frameworks they fit within. Given the benefits of adopting a construct, as well as the plethora of evidence to support the use of self-efficacy within physical activity interventions, it was decided that self-efficacy remained a sensible focus for understanding the exergame experience. Within Chapter Eight of this thesis, the primary discussion takes place. As well as considering the role of self-efficacy within exergames, a more meta approach to the analysis is also considered through a discussion on the various external contributing factors that were identified through the evaluations in Chapter Six and Chapter Seven. Therefore, while this thesis focusses on understanding the exergame experience through the lens of self-efficacy theory, meta level analysis also takes place.

The importance of understanding and applying theories from behavioural psychology within HCI is becoming better understood, with Heckler at al. outlining the merits of using theory to design and evaluate HCI systems [85]. In the next chapter, the literature on exergames is discussed, along with the relative successes and failures of the genre. The work of this thesis goes beyond current understanding, by establishing the role self-efficacy plays on the exergame experience. With self-efficacy established within other domains, this thesis aims to understand its role within the exergame experience, and whether it can be utilised by future exergame developers in order to develop more effective exergame interventions.

2.8 Summary

The purpose of this chapter was to emphasise the importance of children achieving their physical activity targets. Through a comprehensive literature review, this chapter has outlined what physical activity is, why it is important, and the reasons why many children are not meeting the recommended physical activity guidelines.

Addressing physical inactivity is both a large scale and complicated problem, with a complex interaction of factors (social, psychological and environmental) influencing behaviour. It is impossible for a physical activity intervention to target all factors and remove all barriers. As was discussed, it is possible to design and implement effective physical activity interventions with positive outcomes for the participating children. It is, however, also clear that new approaches must be considered, with physical activity participation remaining generally stagnant across much of the Western World.

With the importance of physical activity established, and both the extent of the physical activity problem identified and the factors influencing the problem outlined, the next chapter looks at one potential solution: exergames.

CHAPTER 3

Exergames

With the motivation for conducting a physical activity intervention well established, it is important to consider the current work in the field of exergames. This chapter begins by establishing exactly what is meant by the term exergame, before moving on to provide various examples of commercial and research-based exergaming systems. Following this, the chapter looks in more detail at the areas of exergaming of particular interest to the work conducted within this thesis; *a*) mobile and pervasive exergaming; *b*) exergaming for children and adolescents; *c*) school-based exergame evaluations; and *d*) designing successful exergames.

This literature presented within this chapter provides the motivation for the design decisions which underpinned the development of iFitQuest, in particular why an exergame was suitable for this research, and why adopting a mobile location-aware exergame was the best choice for iFitQuest.

3.1 What is an Exergame?

The name exergame is a concatenation of the words *exercise* and *game*, synonymously known as *Active Video Gaming (AVGs)*. The genre covers video games with the aim of encouraging and facilitating physical activity.

Killi and Merilampi state, "Exergames involve physical activity as a means of interacting with the game and have evolved to facilitate the physical health of the players" [99, p.103]. Similarly, Altamimi and Skinner describe exergames as "video game technology that is based on player motion as the main interaction between the players and game play. These games depend on players' body movements and gestures in the real world to control the objects in the virtual world" [3, p.24].

Most often, the method of facilitating physical activity is an intentional game design choice, for example in the *Wii Fit*. However, it can also be an indirect bi-product, for example *Dance Dance Revolution* (see Figure 3.2 on Page 26) [109].

Figure 3.1: Sports Over a Distance exertion interface [141].

Due to developments in ubiquitous technologies, exergames come in various different forms:

1. **Exertion Interfaces** - Deliberately require intense physical effort in order to interact with the system [142]. One example is the *Sports Over a Distance* exertion conferencing system developed by Mueller and Agamanolis [140, 141], see Figure 3.1.

2. **Machine Exergaming** - Systems that use existing exercise equipment augmented with video games to add additional challenge and enjoyment whilst exercising. For example Nenonen et al's. work on augmenting a traditional stepper machine [149] or Sinclair et al's. work which uses an exercise bike as a game controller [185].

3. **Console Workout Exergaming** - Commercially the most popular type of exergaming, this type of game sees the user exercise while playing a console video game, for example the Nintendo Wii Fit and the popular Dance Dance Revolution (DDR) game (Figure 3.2).

4. **Pervasive Exergaming** - By utilising pervasive computing techniques, pervasive exergaming takes the concepts of console exergaming and moves them out into the real world, allowing for novel game mechanics and support of physical activity not afforded in console exergames. Mobile location-aware exergames fall within this category. *Fish'n'Steps* [115], and the *American Horsepower Challenge (AHPC)* [132, 163, 229, 230], can both be classed as pervasive exergames, while iFitQuest developed for this research is a mobile location-aware exergame.

Within the broad spectrum of *health technology* there also exists a genre loosely referred to as *exercise systems*. While these systems contain many elements similar to

Figure 3.2: Children participating in a Dance Dance Revolution fitness class.

exergames, for example, location tracking, goal setting, or the recording of physiological data, the difference comes from the fact no 'traditional game element' is present. One example of such a system is *UbiFit Garden* [40, 41]. Using a mixture of portable sensors and manual user recording, UbiFit Garden works as an activity diary. The primary feature of the system is a ubiquitous glanceable display, see Figure 3.3. As users work towards their personal exercise targets, flowers in their 'garden' grow, different flowers representing different aspects of fitness. This allows users to easily see their performance in an attractive, and often motivating, manner.

Figure 3.3: The UbiFit garden glanceable fitness tracker.

While lessons can be learned from the evaluation of exercise systems, the exclusion of game elements represents an important distinction between the genres. Thus, the remainder of this literature will focus almost exclusively on those systems which contain traditional game elements, and as such can be classified as exergames.

3.2 Do Exergames Work?

In theory, harnessing the motivating and entertaining aspects of traditional video games, while facilitating physical activity, could prove to be an effective approach to removing some of the barriers to physical activity outlined in Chapter Two. Thus far, the related work in the field has provided only tentative results on whether exergames work. Indeed, the definition of what makes a successful exergame remains open to interpretation. However, it is generally accepted that the goal of an exergame is to promote and facilitate physical activity, within an enjoyable and motivating context. The ultimate goal of an exergame should be to not only promote physical activity, but also promote behavioural change, such that away from the exergame system, the user is more likely to maintain any health improvements.

At the most general level, there exists a body of work which highlights the positive potential of exergames. Murphy et al. found that through a 12-week intervention, DDR was capable of improving overweight children's aerobic fitness [145]. In their investigation of the Wii Fit, Nitz et al. found that a Wii Fit based intervention was capable of improving balance and lower limb strength in a group of middle-aged women [153]. In another study utilising the Wii Fit, Graves et al. found that their participants found the Wii Fit was more enjoyable than traditional approaches to exercise [82]. Studies have shown the potential of exergames to raise the heart rate of the participant sufficiently such that it contributes towards physical activity guidelines [161], while more generally a number of authors have noted that exergames can increase movement and energy expenditure in their players [81, 108, 225]. Peng et al. conducted a meta-analysis of a number of exergame evaluations, concluding that the effects of exergames were similar to that of traditional physical activity, and that they are an effective source of light to moderate intensity exercise [160].

As well as research on commercial exergames, practitioners in the fields of HCI, ubiquitous, and pervasive computing have begun looking at the design, development and evaluation of research-based exergames. The pedometer based exergame, Fish'n'Steps, was evaluated over six weeks, with 19 adult users. Over the course of the study, the authors found evidence of behavioural change in 14 of the 19 participants, as well as a mean increase of 1200 daily steps across the participants [115]. Jensen et al. developed a fun and physically demanding mixed-reality game for university students [95], while Misund et al. found that augmenting traditional playground games with technology could lead to a more enjoyable exergame experience [133].

Other research has shown the potential for exergames to facilitate various additional positive benefits on top of enjoyment and physical activity. Mueller and Agamanolis found that their exertion interface not only required physical activity to play, but also facilitated social interaction and bonding between participants [140, 141].

Trout and Zamora discuss how DDR has been successfully used within P.E. classes as a means to promote teamwork, cooperation, fair play, and creativity [216].

A further advantage of exergames is the way in which they can encourage and facilitate exercise in demographics who traditionally struggle to reach their exercise targets. Exergames have been found to be particularly effective for overweight individuals [156, 217]. Gerling's work looks at exergames for the frail and elderly [75, 76], while other practitioners have targeted exergames towards those with visual impairments [136, 137, 138], mental disabilities [5, 31] and various other physical disabilities such as cerebral palsy [88, 231].

While the literature highlights the positive potential of exergames, the genre remains in its adolescence, and in its current form is by no means a ready-made solution to increasing physical activity, decreasing sedentary behaviour, or facilitating behavioural change. There exists in the field a number of evaluations highlighting the need for further work in understanding exergames.

One Wii Fit intervention, which saw ten middle-aged women use the system twice weekly for 10-weeks found that while balance and lower limb muscle strength improved, the Wii Fit failed to make any significant improvement to the weight, cardiovascular fitness, activity levels, and general physical well-being of the participants [153]. A similar study focusing on adolescent children found that playing the Wii Fit, while more beneficial than playing sedentary traditional video games, did not require the player to expend enough energy during play to contribute towards their recommended daily exercise targets [83]. Similar results were found by White et al. [224].

While the positive influence of Fish'n'Steps has already been discussed, crucially there was a *novelty effect* observed while evaluating the system. Many of the participants began to lose interest in the game, in some cases completely stopping their interaction with the system [115]. A similar novelty effect was observed in the longitudinal evaluation of the American Horsepower Challenge [163, 229], as well as in other longitudinal evaluations of exergames [131, 204]. In the previous chapter, the need for longitudinal use was discussed, without which the physical benefits of physical activity cannot be facilitated. Thus, exergames having a novelty effect represents a problem for the genre, as players must enjoy their experience and remain motivated in order to continue playing and receiving the benefits of the games.

3.2.1 Summary

Thus far, this chapter has outlined what an exergame is and discussed the empirical evidence presenting the benefits and potential issues with the genre. There exists an abundance of evidence to support the use of exergames. Studies exist highlighting the way exergames can facilitate physical activity within enjoyable and motivating environments. However, while there is potential, exergames do not in their current form represent ready-made solutions. Studies have shown that when not well designed, exergames can fail to properly facilitate physical activity. Additionally, longitudinal evaluations have highlighted the problems associated with a novelty effect, that could greatly affect the potential of exergames to facilitate behavioural and physical improvements in their players.

With the genre introduced, the remainder of this chapter looks at exergames in greater depth. First, pervasive and mobile exergames are explored, as iFitQuest fits within this sub-genre of exergames. Following this, exergames evaluated within schools, and targeting adolescent children are discussed, given the target audience and context adopted for the evaluations of iFitQuest. This chapter concludes by discussing those practitioners that have attempted to formalise design requirements for exergames, many of which were considered during the design of the iFitQuest system.

3.3 Mobile and Pervasive Exergaming

While it is important to consider the genre of exergaming as a whole, within that broad umbrella exists a sub-genre of gaming known as *pervasive exergames*. Pervasive exergames are those exergames that contain elements of pervasive gaming. Pervasive games are a type of game “systematically blurring and breaking traditional boundaries” [135, p.1]. Building upon this, Magerkurth et al. state, “pervasive games are no longer confined to the virtual world domain of the computer but integrate the physical and social aspects of the real world” [125, p.2]. Pervasive exergames are those that aim to break exergaming out into the real world, often making use of wearable technology and location tracking as a means to facilitate more flexible exergame experiences played out in the real world of the player. Location-based games are those which utilise the real world location of the player as a primary game input. By tracking the location of the player, the real world can be populated with virtual game elements. The player must move in the real world, in order to interact with the virtual world. By integrating the real world into the game, pervasive games can facilitate greater levels of social interaction and immersion [94].

From a physical activity perspective, by moving away from console based exergames, it is possible to facilitate a greater range of physical activities. For example, location tracking can be used to promote running, which is not possible with console based exergames. Bogost highlights the limits of the living room in his analysis of console based exergames, discussing the technical and logistical issues that can arise from exergaming in the home [29]. Adopting a pervasive gaming approach addresses theses constraints.

PiNiZoRo is a GPS based exergame designed to encourage children to walk more. By tracking the real world location of the player, they must move in the real world to find and fight (using a non exergame method) non player characters [196]. Similarly, *World of Workout* uses GPS to track the distance travelled by the player, with distance used to complete traditional RPG style quests, e.g. "walk 0.25 miles to meet Old Man River" [55]. Chittaro and Sioni evaluated their location-based walking game, reporting that players' became immersed and greatly enjoyed their experience [34]. Mobile location-aware games have also been designed to support higher intensity exercise, such as jogging and sprinting. For example, the adaptive *Monster and Gold* [30] or commercially available *Zombies, Run!* [187].

As well as supporting real world play, pervasive exergames have the advantage in that they can support new paradigms of play. Where as console based exergames require the player to specifically dedicate time towards play sessions, pervasive exergames can 'pervade' into the everyday life of the player. One example of such a game is *NEAT-o-Games*. Through the use of unobtrusive pervasive technology, the movement of the player can be tracked throughout the day and translated into a virtual competition between players [71]. Similarly, Fish'n'Steps is a pedometer based exergame which uses tailored goals and social influence in order to encourage participants to increase their daily step counts [115]. Aimed towards children, the American Horsepower Challenge (AHPC) is another example of a pedometer based exergame. AHPC was designed as an interscholastic step count competition, with children's individual steps combined as a school total and translated to control the movement of a horse in a race. The game pervaded into the everyday life of the player by allowing them to accumulate steps throughout their whole day, despite the primary context being the school [132, 163, 229, 230].

In summary, pervasive exergames cater for new styles of play, are supportive of richer social interaction, and support a greater range of physical activities that would not be possible with console based exergames. While the research questions of this thesis could theoretically have been answered through the development of a non-pervasive exergame, for the aforementioned reasons, as well as the tentative research on the success of such a genre for children [133, 163, 211, 229], iFitQuest was designed as a mobile location-aware exergame.

3.4 Exergames for Adolescents

In the previous chapter, the justification for targeting adolescent children was discussed by presenting evidence highlighting the need to increase the amount of physical activity children engage in, as well as minimise sedentary behaviour. It is therefore important to consider other practitioners that have begun designing exergames for this demographic, as well as those that have been evaluated within a school-based context.

One of the main motivating factors behind exergames for adolescents is the fact that as a demographic, they are already regular players of traditional video games. A recent study of the game playing habits of US teenagers found that 97% play computer games, with 52% playing 3-5 times a week or more. Half of respondents played video games for one hour or more on the previous day to the study [114]. Therefore, by harnessing this desire and dedication of time, exergames could help adolescents increase physical activity whilst enjoying an activity they already persue and spend time doing. Mellecker and McManus [129] and Maddison et al. [124] have observed the health benefits of transitioning from traditional video gaming to exergaming.

Some practitioners have begun to look at how children react to exergames. Perron et al. for example looked at how playing two Wii based games influenced the heart rate of the players [161]. Christison and Khan investigated how exergames could fit within the greater context of a multifaceted weight intervention program. Outcomes of the trial emphasises the potential of exergames for weight management, with children significantly reducing their BMI post-intervention [35]. Maddison et al. found that adolescent children can lower their BMI and body composition through exergame play [123]. Graf et al. found that exergames for children represent a “safe, fun, and valuable means of promoting energy expenditure” [81, p. 534].

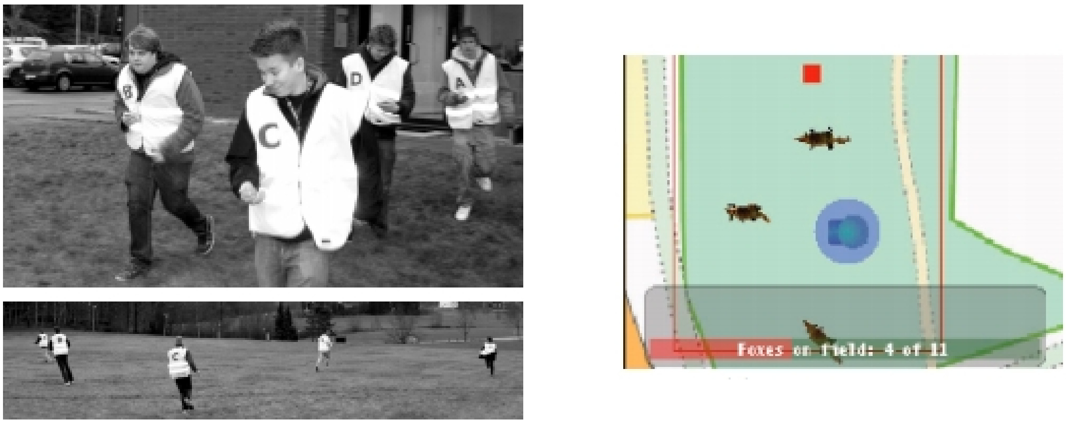


Figure 3.4: Playing the FoxHunt game (left) with a view of the game interface (right) [133].

While some early results appear positive, there exists a body of work that highlights the potential issues of exergames for this demographic. White et al. investigated a number of console based exergames with adolescent boys and found that energy expenditure was not intense enough to contribute towards daily physical activity targets [224].

While some researchers have looked at how effective commercial exergames such as DDR [145, 216, 217] and the Wii Fit [82, 161] are for children, others have looked at developing research based exergames. One notable example is the previously mentioned, AHPC. Players in this game wear a pedometer to measure their step count, which is then combined with their peers to represent a school total, used in an interscholastic competition with other participating schools. Researchers found that such a pervasive system could effectively be used to raise the step counts of the participants [132, 163, 229, 230]. Through a large scale evaluation, Misund et al. found that their mobile location-aware exergame *FoxHunt* (Figure 3.4) provided an enjoyable experience for children, irrespective of a background in sport or their gender [133]. This highlights the positive potential of such games to appeal to a wide demographic of players. An overview of the related work in the field of exergames for children is provided by Altamimi and Skinner [3].

Looking in more depth than general success, some practitioners have begun investigating what makes for a successful exergame for children. Marijke et al. found that multiplayer exergames are particularly motivating for adolescent children, with their study highlighting increased play frequency and lower evaluation dropout when a system was multiplayer [158]. Similar results were found by Arteaga et al., although they also advocate the use of single player exergames, as the background of the child will influence from where they draw their motivation [7]. *Play Mate!* uses virtual incentives to increase the enjoyment and amount of physical activity performed by children whilst playing a balance based exergame [23]. *Chick Clique* uses raised social awareness and peers support as a means to persuade adolescent females into achieving their exercise goals [211]. Xu et al. investigated different player types within a pervasive exergame, highlighting tensions between the individual and group within a collaborative exergame competition [230].

3.4.1 School-Based Exergame Interventions

In the previous chapter, the importance of context on the success of physical activity interventions was stressed. With the decision made to develop the system for a school context, it is important to consider other exergames that have been developed for and evaluated within such contexts.

Through a concise literature review on the potential of exergames for physical education, Papastergiou highlights the potential of exergames as a means of improving fitness and aiding in skill acquisition, particularly in those demographics that need it most, such as overweight children [156]. Fogel et al. found that exergames provided more physical activity than a standard P.E. program, and that such systems were socially acceptable to both the children players and teachers [67]. These findings have since been replicated with another sample of children [183]. Some physical education practitioners have also begun looking at the way commercial exergames can be integrated into the school curriculum as a potential alternative to more traditional P.E. activities. For example, Trout and Zamora looked at the way Dance Dance Revolution (DDR) could be used within a P.E. lesson, providing guidance on how DDR can be used not only to facilitate physical activity, but also as a teaching tool [216].

In depth studies of the way exergames can be used within schools also exist. Xu et al. highlight the importance of the teacher as a social tool in the success of a school-based pervasive exergame, the AHPC [229]. These results were clarified by Miller et al., who highlight that the teacher is as much a user as the children playing the game, and is essential to the successful deployment of an exergame system within a school context [132]. In another study on the AHPC, Poole et al. highlight the importance of the school environment on the success of an exergame intervention. As well as confirming the positive potential of exergames for this context, the authors found that for successful deployment, both exergame systems and the school context must be flexible to accommodate for optimal use, and that 'group experiences' can be effective motivators [163]. The importance of multiplayer exergame systems for P.E. is emphasised by Killi et al., who found through an evaluation of two exergame systems, the engaging nature of cooperative multiplayer play [100].

3.4.2 Summary

Concluding her literature review, Marina Papastergiou states, "exergames may constitute ideal vehicles for promoting regular physical activity among children, adolescents and young adults, who may be reluctant to participate in traditional types of exercise...and, most importantly, that exergames are efficient in helping populations who most need them, such as...adolescents" [156]. In this section a number of exergames have been discussed, highlighting the potential of the genre for targeting children, increasing their physical activity and decreasing the proportion of their time spent in sedentary activity. Staiano and Calvert highlight that while there is positive potential, the work in the area of exergames for children is "limited" [195], a stance reemphasised by Papastergiou [156]. There is thus a need to further evaluate the suitability of exergames for targeting children, and integrating into the school context.

Additionally, while some practitioners have begun looking in depth at the exergame experience, by looking at ways to increase motivation and enjoyment, there remains a gap in the literature. The motivation for this work comes from the need to understand how the self-efficacy of the participant can influence their experience and whether it can be harnessed to promote increased motivation and enjoyment. Crucially, this requires longitudinal evaluation. A key concept within physical activity interventions, currently the field of exergames falls short in this respect.

3.5 Evaluating Exergames: Longitudinal Evaluation

In the previous chapter, a number of physical activity interventions were discussed. Key to the success of each was the notion of longitudinal evaluation. In order to facilitate behavioural change, evaluate how well an intervention facilitates physical activity, and properly evaluate whether physiological improvements to health have been observed, the interventions must be run over a prolonged period of time.

The same is true for exergame evaluations. While lab-based, single session studies are an effective means to evaluate a 'proof of concept' - i.e. whether an exergame can facilitate physical activity and provide enjoyment to the user - for a true insight into how an exergame can influence the motivation of the participants and help with improvements to fitness and health, a longer term, intervention style evaluation is required. However, within the field of exergames, such approaches to evaluation are often not considered. Concluding her literature review on exergames, Papastergiou states, "further empirical investigation is needed, based on longitudinal research designs and larger samples, with a special focus on populations most in need of exercise" [156].

As Klasnja et al. discuss, longitudinal evaluation of technologies to encourage behavioural change is difficult in nature [103], citing Prochaska et al.'s literature review which states that for behaviour changes to be maintained, a person must meet their target for several years [164]. To this end, Klasnja et al. state, "Unless we have really conducted such longitudinal studies, we should not make claims that participants in our studies truly changed their habits" [103, p.3064]. However, Klasnja et al. conclude that 'tailored efficacy evaluations', and evaluations that look in depth at participants' behaviour, can both be used to show that a system is working, without the need for full scale, longitudinal randomised control trials [103]. Thus, while multiple year evaluations may not be necessary, more prolonged use of exergame systems is essential.

Much of the related work in the field fails to adhere to the above considerations. Some of the aforementioned exergame studies were designed to establish the physiological cost of exergames (e.g [81, 82, 108, 161]), and to an extent this can be assessed from lab-based single usage studies. For those exergames targeting physically disabled [5, 31, 88, 231], or elderly [75, 76] users, longitudinal evaluation can be made more complex.

However, when attempting to fully understand the impact of exergames, longitudinal evaluation is the only approach which can truly be used to understand the genre. Despite a large sample size of 220 players, the results of Misund et al. were based on a single 4 minute play of their game [133]. *Exerlearn Bike* [2], *Astrojumper* [66], *LocoSnake* [34], *Play Mate!* [23], *World of Workout* [55] and *SNAP* [225], as well as the findings of [30, 95, 100], were all based on single usage studies. Meanwhile, *PiNiZoRo* was evaluated over a single session, with only four participants, all of which were outwith the target demographic [196]. While none are guilty of making overstated claims with regards to behavioural change, they do fail to evaluate their systems beyond basic pilot study proof of concepts. Assertions about the suitability of exergames as a tool to facilitate physical activity, or behavioural change, as well as any guidance provided on the development or deployment of such systems, must therefore be interpreted with caution.

In her 2008 literature review, Marina Papastergiou calls for more longitudinal evaluation, "further empirical investigation is needed, based on longitudinal research designs and larger samples" [156].

Some practitioners assessing the potential of exergames to affect the health and fitness of their participants have conducted multiple week interventions, for example Murphy et al. [145], Nitz et al. [153], and Maddison et al. [123], all of whom were assessing commercially available exergames such as DDR, Nintendo Wii Fit, and the Microsoft Kinect.

As has been discussed, there are few examples of research based exergames being evaluated longitudinally. There are, however, notable examples, such as the AHPC, and Fish'n'Steps.

The previously discussed AHPC pervasive exergame was evaluated in 61 schools across the United States, with over 1000 children participating in the game. Each student played the game for a minimum of one 'heat', which lasted 4- to 5-weeks, while some participated for the maximum of three heats. As has been discussed, the prolonged evaluation allowed the authors to add evidence to the potential of exergame usage within schools, as well as providing a number of design considerations and logistical insights into exergame evaluation [132, 163, 229, 230].

Fish'n'Steps is another pedometer based exergame that has been evaluated longitudinally. Over the course of a 6-week intervention, 19 participants played the exergame, which harnessed personalised goals and social influence to motivate participants towards achieving their daily step counts. Through a prolonged evaluation, Lin et al. were able to apply the *Trans Theoretical Model* of behavioural change to establish how their system affected the long term attitudes of the player, and thus the potential for lasting impact [115].

Importantly, as was discussed in Section 3.2, the evaluations of the AHPC and Fish'n'Steps highlighted the prevalence of a 'novelty effect'. As participants began to get bored with the system, their motivation decreased and so too did the amount of physical activity they got whilst playing a game. Similar results were observed by Sun [204] and Mhurchu et al. [131] who ran a 4-week and 12-week exergame intervention respectively. While lab-based evaluations may highlight the potential of exergames to facilitate physical activity, if in reality they are not sustainable over prolonged periods of time, they will prove ineffective as a tool to promote healthy behaviour. Without longitudinal evaluation, such an effect would have not have been discovered, providing evidence for the efficacy of such an approach to evaluations.

3.6 Designing Exergames

Already within this chapter, a wide variety of exergames have been presented, coming in various forms and targeting a range of demographics. While much of the work remains tentative, and based upon proof of concept evaluations, there does exist a small body of work which aims to provide design guidelines for future exergame practitioners. Although, in some cases, the logic behind certain decisions is based on very tentative results, it is still important to consider the related work in the field.

Consolvo et al. outline four key principles for the development of pervasive exergames, having evaluated their exergame *Houston* [39]. Their findings were:

1. Give users proper credit for their activities;
2. Provide personal awareness of activity level;
3. Support social influence;
4. Consider the practical constraints of the users' lifestyle;

While useful, these requirements come from a system looking more towards activity logging, i.e. the player goes jogging and the system must track their exact distance and time. It is therefore a sensible conclusion that the system must always give users proper credit for their activities and provide full awareness of activity levels. However, in a system designed for children, and with a richer game element, a balance must be found between full activity awareness, game immersion and enjoyment.

Although more generally targeting 'everyday fitness applications', Campbell et al. [32] outline what they believe to be the 7 key principles for exergames by considering successful fitness applications and online multiplayer games. Practitioners should consider:

1. Core Mechanics - The key interactions in a game, and the way in which a designer can influence the formation of physical habits;

2. Representation - The aesthetics and narrative, from which the player will derive enjoyment;

3. Micro Goals - The small scale challenges and tasks which the user must complete. By including micro goals, the user receives regular gratification and feedback as well as providing a mechanism to track overall progress;

4. Marginal Challenge - In order to encourage flow and fun, challenge level must be set to an appropriate level;

5. Free Play - The ability of the player to choose their path through the narrative, with maximal choice a favourable option;

6. Social Play - The game must be designed to encourage social play of the participants, both within the game and externally;

7. Fair Play - It is important that all players have a level playing field when participating in a game;

Although Campbell et al. do not test these principles within their own purpose built application, they were established through an analysis of existing exergames.

At a more general level, Suhonen et al. [203] provide advice on how to promote health awareness while maintaining engaging and enjoyable gameplay. While not specific to exergames, a number of their guidelines are applicable to iFitQuest, and exergames in general:

1. Support social aspects of gameplay and interaction;

2. Provide mobile games that are easy to learn and approach;

3. Provide an extensive game world with the possibility to explore and interact freely with it;

4. Provide appropriately challenging tasks and features that provide feedback and show players improvement;

Through an evaluation of a number of existing exergames, Arteaga et al. found that *Variety* and *Appropriate Challenge Level* were essential for successful exergames, while games should support both single and multiplayer experiences to suit the background of the player [7]. Similar justifications for multiplayer experiences have been made by Killi et al. [100] and Poole et al. [163].

While not providing concrete sets of design requirements, various other practitioners offer insight into their development considerations, and the subsequent impact of the effectiveness of their exergame. Smith discusses the need for short loading times, due to impact on physical activity between games [190], while Yim and Graham stress the importance of both short and long term goals to enhance motivation within exergames [233].

Munson and Consolvo discuss the benefits of goal setting and rewards. Their work highlights the increased player motivation associated with primary and secondary goals, while traditional in-game rewards such as trophies provided no additional benefit to the exergame [144]. Bekker et al. discuss the merits of motivating feedback, open-ended play and social interaction within systems targeting physical play [22].

The design of iFitQuest is outlined within Chapter Four, while the final system and adopted design requirements are outlined within Chapter Five. The influence of the aforementioned papers had on the design of iFitQuest is stressed at that point.

3.7 Exergames as Persuasive Technology

Commonly used within the field of HCI, the term *Persuasive Technology* refers to systems that "use computers to change what we think and do" [68]. By this logic, to many, exergames may be seen as an example of persuasive technology. However, the term has become more controversial in recent years. As Hekler et al. write "a classic label for behavior change technologies was persuasive technology. While not intended, persuasive technology implicitly suggests some degree of coercion by persuading individuals to engage in an action that they might not otherwise want to engage in. On the basis of this, many in the HCI community are choosing to use other terms such as behavior change technologies. This shift in terminology reflects a larger desire among those building behavior change technologies to consciously support an individuals personal agency rather than unintentionally coercing them." [86, p.29]. Recent work has raised questions on whether persuasive systems are truly persuasive or in fact coercive, as well as the ethical implications of persuasive system design [166].

In Chapter Four, the design process undertaken for iFitQuest is outlined. Ahead of this, it is important to distinguish between the goal of the iFitQuest exergame and the current understanding of persuasive systems. In Section 3.2, the generally accepted goal of exergames was outlined. While the primary purpose of an exergame is to promote enjoyable and motivating physical activity, the long term goal of such systems is to promote behavioural change. However, coercion does not fit within the design philosophy of iFitQuest. Outlined within the next two chapters, iFitQuest supports player agency in a number of different respects, with freedom, flexibility and customisation key concepts which underpin the system. Rather than directly steer certain players into undertaking tasks they do not desire, iFitQuest supports and encourages players to take control over their exergame experience. Indeed, the goal of iFitQuest is to show players that physical activity can be enjoyable and motivating, rather than forcing them to play a game that they might not otherwise wish to play. It is for this reason that iFitQuest is better classed under Hekler et al.'s definition of *Behaviour Change Technology* [85] rather than persuasive technology.

3.8 Summary

The purpose of this chapter was to highlight the related work in the field of exergames. After initially explaining the diverse range of systems within the genre, the chapter focussed on those exergames relevant to this thesis.

Through a literature review, the positive potential of exergames was outlined, with evidence presented highlighting the way they can facilitate physical activity within enjoyable and motivating contexts. Importantly, such evidence also exists for the target audience of this thesis, adolescent children. However, while some practitioners have begun looking in greater depth at the exergame experience, areas for further work were highlighted. In particular, the presence of novelty effects and a general lack of longitudinal evaluation highlight the need for more exergame practitioners to conduct in-situ, longer term evaluations. Related to this, and building upon the work highlighted in the previous chapter, the way in which self-efficacy could influence the exergame experience and be utilised to develop more effective exergames, has not been investigated, with only a limited number of practitioners looking beyond the general exergame experience. With the influence of self-efficacy stressed within the previous chapter, understanding its role within exergames could prove to be one method of addressing novelty effects and raising the validity of the genre.

Further to this, the decision for developing iFitQuest as a mobile location-aware exergame was justified by reviewing the success of similar exergames, in particular those that target children and school-based contexts.

At this stage, the justification for targeting adolescent children, developing a mobile location-aware exergame for a school context, and investigating self-efficacy through a longitudinal evaluation has been made clear. In the next chapter, the design and development approach adopted for iFitQuest is outlined, a prototype driven user-centred design approach.

CHAPTER 4

The Design of iFitQuest

This chapter describes the design and development of iFitQuest, the mobile location-aware exergame developed as the focus of this research.

The chapter begins with a summary of the focus of the iFitQuest system, based on the findings of the two literature reviews presented within Chapters Two and Three. With this clarified, this chapter then moves on to describe the methodology used for the development, an iterative and prototype driven, user-centred design approach. The chapter then moves linearly forward, covering the main development iterations undertaken during the development process; (i) Initial requirements gathering focus groups; (ii) Prototype 1 development and evaluation; and (iii) Prototype 2 development and evaluation.

During each phase, the purpose of the work, the findings during that iteration, and how the findings influenced subsequent development iterations are discussed.

4.1 iFitQuest

In Chapter Two, the related work in the field of health and fitness literature was outlined. The literature review provided the motivation for a system designed to target adolescent children, for use within a school-based context. The literature also outlined the need for a system capable of facilitating physical activity, ideally at a moderate to vigorous intensity, as well as the benefits of avoiding sedentary behaviours (and thus the benefits of light intensity physical activity).

In Chapter Three, the potential of exergames to facilitate physical activity was outlined. In particular, the merits of pervasive exergames were discussed, motivating the design and development of iFitQuest as a pervasive location-aware exergame. Practitioners who have begun providing design guidelines for exergames were also discussed. The way in which such design consideration were incorporated within iFitQuest is stressed throughout the next two chapters.

Due to the context adopted and demographic targeted, the design and development of iFitQuest was exploratory in nature. While pervasive exergames have been evaluated in the past, and practitioners have begun providing general design guidance for exergames, a mobile location-aware exergame like iFitQuest has never been fully evaluated in a prolonged usage school-based study.

The research questions posed within Chapter One outline the desire to understand the exergame experience, in particular the role self-efficacy can play on the behaviour and attitude of the participants. In order to cater for emergent behaviours, iFitQuest had to provide the player with a flexible environment in which they could make their own choices and cater the exergame to their own needs. A heavily constrained environment would not allow for different emergent patterns of behaviour. Thus, while one focus of this thesis research was to attempt to create an effective exergame for this demographic and context, the other was to better understand the experience through the development of a flexible and exploratory system.

The remainder of this chapter outlines how such a system was achieved, through a user-centred design process, which included the design, development and evaluation of various prototype systems.

4.2 User-Centred Design

User-Centred design (U-CD), the process of utilising end-users to aid in the design process of a system, is common practice with the IDC community, see [56] for an overview of the process, and [90] for a snapshot of its prevalent use. Game design practitioners argue the importance of including the players during the design process [64, 167] and, despite the relatively recent emergence of exergames, there exists a small body of work highlighting the merits of adopting U-CD for developing effective exergames. Toscos et al. used such an approach in order to cater their system Chick-Clique towards adolescent females [211], while Gerling and Masuch recommend the use of U-CD for developing exergames for an elderly audience [75]. U-CD was also effectively used by Romero et al. when trying to establish the design requirements for their exercise system [171]. Thus as U-CD is common practice with both those working with children and those designing exergames for a specific target demographic, it was logical to adopt such an approach for this development. Additionally, prior research has shown that understanding the context of a health promotion program, for example schools, homes or communities, is essential to the successful design and implementation of the program [46, 105, 127, 199]. To this end, not only the children playing the exergame are considered as the users of the system, but also the teachers who will be implementing its use into their curriculum. Teachers as users was emphasised by Miller et al. during their work on the AHPC [132]. Therefore, a U-CD approach not only encourages the opinion of the target players, but also allows teachers to provide feedback on how they see the system fitting within the context of their classroom. Each phase in the U-CD approach adopted for the development of iFitQuest not only included children, but also teachers and physical activity experts.

The adopted development approach follows the structure outlined by Boehm in his work on the *Spiral* development methodology [28]. The development followed an iterative, prototype driven approach, with the users aiding the process during each iteration. Choosing this approach has a number of merits:

1. The end-users are consulted throughout the process, allowing for their feedback to be utilised at all stages of the development.
2. By rapidly prototyping, end-users can tangibly see their feedback and how it is influencing design.
3. With interactive systems such as games, it is often difficult to elicit requirements from an end-user. Evaluating prototypes helps validate the requirements gathering process and correct problems early on in the development.
4. The risk of developing an ineffective system is mitigated by regularly assessing progress with end-users, rather than waiting until the end of the development.

For this development, users were classed as *informants*, utilised throughout the development process without being equal stakeholders [56].

4.3 Overview

The development methodology for iFitQuest contained four primary phases:

1. **Early Requirements Gathering** - An expert interview and two focus groups.
2. **Early Prototype Development** - Initial high fidelity prototype with preliminary user evaluation.

3. **Prototype refinement and extension** - Extension and refinement of the initial prototype with further user evaluation.

4. **Final system development** - Development of the final iFitQuest system with two full empirical evaluations.

These phases generally follow the well established game design phases of (i) Conceptualisation (ii) Prototyping (iii) Playtesting [72].

The four phases of this development approach are summarised in Figure 4.1. The remainder of this chapter moves linearly through the first three phases of the development.

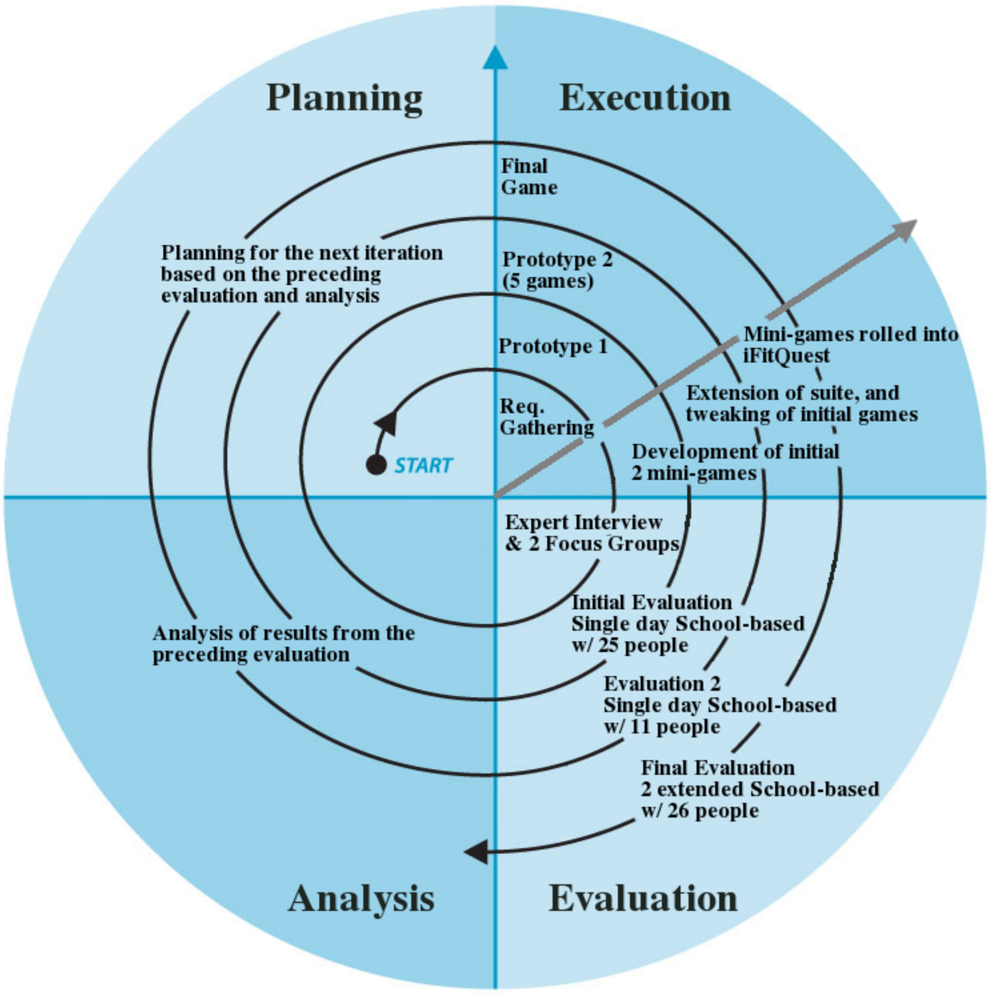


Figure 4.1: Overview of the four main development phases.

4.4 Requirements Gathering

The first stage in the development process was a high-level requirements gathering exercise. Although, as was outlined in Chapter Three, there exists a large body of exergame literature, there are few research based exergames that have been developed exclusively for adolescent children or for within a school context. Therefore, in order to develop a desirable exergame, early research focused on assessing the wants and needs of the system's target users, both the adolescent players and the classroom teachers. It was decided that the initial stage should be an expert interview. By consulting a P.E. teacher, contextual constraints and exercise requirements could be established before beginning the consultation with the end-user. This way, there would be a greater understanding of the proposed system, before considering game themes and content.

4.4.1 Expert Interview

The purpose of the expert interview was two fold. First of all, to establish whether the findings of the literature review were consistent with the opinion of someone who had first hand experience of encouraging adolescent children to exercise. In the opinion of the expert, was it correct to target adolescent children, and did she believe that exergames could feasibly help with the promotion childhood physical activity. Second of all, the purpose was to elicit contextual requirements to aid in the design of the game, i.e. what was required to develop an exergame such that it can effectively fit within a school context, while appropriately targeting adolescent children.

An experienced P.E. teacher (the head of a P.E. department) was recruited from a local high school. Over the course of a single one hour session, the teacher was interviewed. Two researchers were present, one to ask the questions while the other recorded the interview and made notes. The remainder of this section highlights the main questions asked and provides a summary of the experts answers.

Who should the system target? The expert agreed with the literature, observing that between the ages of 12-16 there is generally a drop-off in fitness, attitudes towards exercise, and exercise participation. She observed that this becomes more prevalent when pupils enter their 3$^{\text{rd}}$ or 4$^{\text{th}}$ year at school (ages 13-16). The expert also added that generally her pupils had "poor" fitness levels, confirmed by fitness tests she had done with all of her classes. She stated that 5 minutes of exercise will exert many of her pupils, and even the fitter pupils will struggle to exercise for 20 minutes.

How do you feel about exergames and their application within schools? The expert was open to using exergames in her curriculum, although she had not done so yet. The expert emphasised the need for fresh approaches in order to counter deteriorating attitudes and fitness. However, before incorporating exergames she wanted to see more empirical evidence as to their suitability and effectiveness.

How are P.E. lessons generally organised? The expert provided an overview of how P.E. worked within a high school context. School lessons are 55 minutes long, and each child gets at least one P.E. lesson per week (more if the child takes a certificated P.E. course in their 3rd or 4th year). Within their class, pupils generally do one activity for a 6 - 8 week block, with core classes not split by ability. An individual lesson (55 minutes) is generally structured as follows:

Warm-up 5 minutes

Stretch 5 minutes

Exercise 15 minutes

Cooldown 5 minutes

The rest of the class is spent getting the pupils to and from the P.E. department, changed for the lesson and showered after the lesson.

How do you cater lessons to an individual pupil? The expert commented that generally lessons are not tailored to the specific needs of the student. However, children are taught from 1st year how to assess their perceived levels of exertion, with self-reporting generally used to assess how hard they are working. In certain lessons, the teachers will work with the students to create goals and challenges in order to push the student. Key is the fact that students are also taught how to create their own goals and challenges.

How should the 'Physical Activity' aspect of the system be approached? The expert believed that all exergames should target specific aspects of fitness, but that the commercial exergames she has used do not meet this requirement. The expert therefore felt exergame designers should think carefully about different aspects of fitness, the training methods that are traditionally used by coaches and experts to facilitate fitness improvements, and how these drills could be incorporated into a game.

P.E. class observation In addition to the interview, the expert recommended that an observation of a 'traditional' P.E. lesson was conducted, in order to see how lessons were generally structured and how the pupils generally behave. During the observations, the attitude problems of the pupils became apparent, with the children appearing unenthusiastic and easily distracted. The children needed a lot of encouragement, and generally chose to socialise with one another rather than participate in the physical activity. The observation also provided an opportunity to see how P.E. lessons are set-up, with short bursts of activity, in order to cater for short attention spans and poor fitness levels.

4.4.1.1 Summary

The interview with an experienced P.E. teacher, and the observation of a traditional P.E. lesson, provided reassurance that the proposed target audience was correct, and that exergames are a potentially viable option for the P.E. classroom. The expert also provided useful feedback on the school context, providing a set of initial design considerations for the exergame. In order to build upon the initial considerations, focus groups involving the target demographic were conducted.

4.4.2 Focus Group 1 - Gaming Requirements

The second stage of the requirements gathering iteration was a focus group with participants from the target-user demographic. The purpose of the focus group was to gather information on the gaming interests of children within the target demographic. In particular, what type of game the participants enjoyed playing and what mechanics were important to an enjoyable game.

Six 13 - 14 year old children (3 male and 3 female) were recruited from a local high school. The focus group was semi-structured, containing round-table discussions and card sorting exercises. A full report of the focus group is contained within Appendix E. To summarise the findings:

1. As expected, there was no clear genre or mechanism which stood out against the others. This confirmed the difficult challenge of trying to cater a game to a wide range of requirements and interests.
2. The game must be simple and thus easy to pick up and play. It is important that the learning curve is not too steep as this could result in demotivation. The pick up and play nature is also important from the perspective that the game will be implemented in a school context which constrains the time available to play the game.
3. The game must be open in the sense that the player is allowed creative freedom and is capable of making decisions which will influence the game.

4. The game must have an overriding goal.
5. A good feedback system is essential to stop people becoming confused and side tracked.

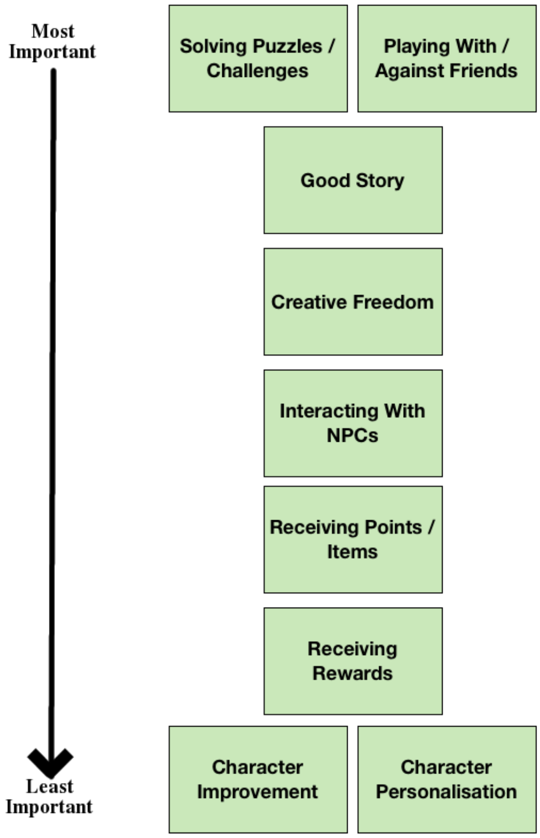


Figure 4.2: Example output from the 'game mechanic' card sorting exercise used in focus group 1.

4.4.2.1 Summary

The focus group served to confirm that within any demographic, there will be disparate interests when considering video games. While none of the feedback given directly influenced the content or theme to be used for the game, it was possible to elicit certain desirable mechanics and design requirements.

An additional take away point was the trouble the participants had expressing their needs. This was compounded by the fact that only 1 of the 6 participants had ever played an exergame. When considering a demographic which will likely have no game design experience, it is a difficult task to expect them to provide feedback on design requirements, especially for a game genre with which they are not familiar. For this reason, the next stage of the requirements gathering process had children from the target audience play an existing exergame and provide feedback.

4.4.3 Focus Group 2 - Exergame Playthrough

The aim of the second focus group was to establish general opinion on exergames from those with no prior exergame experience. Additionally, by allowing participants to experience an exergame first hand, it was hoped that they could provide meaningful advice and guidance on desirable exergame features.

The same six participants from the initial focus group were recruited (3 male, 3 female, aged 13 - 14). Each participant was allotted time to play a Nintendo Wii based exergame, Wii Fit. Each participant was then interviewed on their experience, after which a structured round table group discussion was held. A full report on the focus group is contained within Appendix E. To summarise the findings:

1. Generally, feedback was positive towards exergames, with participants enjoying the experience and surprised by the standard of the games.
2. A complex social dynamic was observed, with the females initially refusing to exercise individually in front of the males.
3. The users liked the points system, in particular as a means for validating performance.
4. 'Pick up and play' is an important concept, with participants losing focus or becoming frustrated during prolonged breaks.
5. Despite being able to express preferences regarding existing exergames, the participants still struggled to conceptualise game design ideas for a mobile exergame.

4.4.3.1 Summary

While it was useful to see how new users responded to an exergame, once again the participants found it difficult to conceptualise their wants and needs. Despite this, observing behaviour during exergame play provided information on what motivated and frustrated the participants. The focus group also provided the first insight into the complex social ecosystem that works within schools. Notably, the female participants were reluctant to play in-front of their male peers.

4.4.4 Conclusions

The aim of the initial development iteration was to gather game design requirements and elicit feedback to aid in designing the themes and content for iFitQuest. Based on the requirements gathering exercises, it was possible to establish the following design requirements for the initial prototype development:

1. **Quick Start** - Based on the time constraints of a school curriculum, and the frustrations observed in the second focus group session, the exergame should have a quick, 'pick-up and play' style.

2. **Short Bursts** - Based on the style of activity observed in the traditional P.E. class, the short attention spans observed in the focus groups, and the physical activity advice of the expert, the game should be comprised of short bursts of activity.

3. **Flexible Sessions** - Based on the advice of the P.E. teacher, the sessions should be flexible in length, as various factors can influence how much of a 55 minute period can actually be used for class time.

4. **Self-Reporting** - As children are taught from an early age how to gauge their own exertion levels, it is feasible to utilise self-reporting within the exergame system.

5. **Personal Awareness** - Based on the above, the system should raise the players' awareness of how much physical activity they are performing.

6. **Focused Activities** - The interview with the P.E. teacher highlighted the need for focused exercise activities. For maximal effectiveness, the exergame should consider different intensities and types of physical activity. Thus, while an exergame must have the general goal of promoting MVPA, and preventing sedentary behaviour, inspiration on how to facilitate this should come from consideration of traditional approaches to PA seen within P.E. classes.

7. **Free Play** - In the initial focus group a consistently desirable mechanic was the aspect of free play. The game should thus be open in the sense that players can make decisions which influence the exergame experience.

8. **Macro Goals** - Another consistently important concept established during the initial focus group was the idea of an overriding goal. Thus, the exergame must have an overriding goal to help with motivation across multiple plays.

Unfortunately, while a plethora of useful information was gathered during the early requirements gathering exercises, it was not possible to gather specific suggestions on how to design the themes and content of the game. The focus groups served to highlight the disparate interests of the target demographic. However, through the design guidelines established above, and the pre-existing advice from the exergame literature, outlined in Chapter Three, it was possible to continue with the development of a framework for the game. Themes and content could therefore be loosely based on the advice from the focus group participants and refined over subsequent prototype evaluations.

4.5 Prototype 1

This section provides an outline of the first exergame prototype and the subsequent preliminary evaluation. Due to the ease of rapid mobile application development, it was decided that the development approach should focus on a high-fidelity prototype. The focus groups during iteration one highlighted the merits of allowing children to test a product in order to provide valuable feedback. As such, low-fidelity prototyping approaches were skipped in favour of rapidly developing a working system. The goal of the initial prototype iteration was to develop a working location-based game that could track the real world movement of the player and utilise this as a game input in order to encourage physical activity.

4.5.1 Initial Prototype

The initial prototype consisted of two mini-games, each taking the form of separate iPhone applications (the justification for developing for an iPhone is outlined within Chapter Five). This section provides an overview of the games, highlighting how each builds upon the related literature and the previous requirements gathering exercises.

4.5.1.1 Mini-Game Approach

Mini-Games refers to games with simple, easy to understand game-mechanics which usually last for a short period of time, i.e. 30 seconds to 5 minutes. It was decided that to meet the initial game design requirements, developing a ‘suite of mini-games’, with each game following the same overall theme, would be an effective approach. With an exergame of this style, a gaming session would be comprised of a series of mini-games. The merits of such an approach are:

1. By adopting mini-games, the player will never spend a significant amount of time on one single activity. This is advantageous given the *Short Burst* requirement related to the short attention span of the target audience, and the way traditional P.E. lessons are set-up.

2. Mini-games allow one exergame to support a number of different aspects of physical activity, when each mini-game is designed with a different primary considerations.

3. Mini-games allow for variety in gameplay and style, with the aim of catering to a wider demographic of player.

4. As mini-games usually contain simple game mechanics, they allow for a *Pick up and play* philosophy, providing new players with a shallow learning curve, and meeting the *Quick Start* requirement.

5. By setting up a session as a series of mini-games, the system is flexible to the constraints of a school curriculum. A session can be constructed of as many or as few mini-games as is required to fill the time slot. As mini-games are short in length, a child is unlikely to have to quit in the middle of a game. This meets with the *Flexible session* requirement, as well as allowing the game to be catered to different fitness needs.

6. By providing a number of mini-games, players can be provided with *Free Play* in terms of which mini-games to play and in what order.

7. Exercise based mini-games can be utilised to construct an effective 'interval' style training session, in which the player performs short bouts of physical activity intermittently split with rest time.

With a mini-game approach selected, the initial prototype focused on two potential mini-games for the suite.

4.5.1.2 Development Approach

As was outlined earlier in the document, iFitQuest was to be designed as a location-aware pervasive exergame, the motivation for which was discussed within Chapter Three. Due to the iterative nature of the development approach, early prototypes were also developed as location-aware games, such that future iterations could naturally build upon the earlier work, towards a final system. The prototype mini-games outlined in this section were developed for the iPhone, and utilising GPS technology for real world location-based play. The motivation for the software and hardware adopted for the development is discussed in Chapter Five, Section 5.2.2 and 5.2.3. The purpose of the work in this chapter is to highlight how the system evolved, and how the feedback of the participants was utilised for subsequent developments.

4.5.1.3 Collect the Pacdots

Collect the Pacdots takes influence from the retro game *Pac-Man* [147]. The goal of the game is for the player to collect a predefined number of 'pacdots' as quickly as possible, while simultaneously avoiding a patrolling ghost, see Figure 4.3. The pacdots are dynamically generated based on the real-world location of the player when the game is started, with the number of dots to collect dependent on the games current difficulty level (the game defaults to one pacdot; this is increased or decreased by one based on whether the player wins or loses the preceding game).

Figure 4.3: Collect the Pacdots screenshots.

In order to 'collect' a pacdot, the player must physically move in the real world towards one of the pacdots in the virtual world. When the GPS location of the player is within a threshold distance from the GPS location of the pacdot, it is collected. Audio and vibro-tactile output confirms that the pacdot has been collected, and the counter in the top-right corner is increased (see Figure 4.3). Much like collecting the pacdots, if the GPS location of the player gets too close to the virtual GPS location of the ghost, then the player loses the mini-game. The ghost does not actively pursue the player, but rather patrols at random within the vicinity of the pacdots.

This game was designed to support a variety of exercise intensities, as the game could feasibly be played by a player travelling at any speed. The design of the game was made with agility training in mind, as the player is expected to run between pacdots, with sharp direction changes to avoid the ghost and move towards the next target.

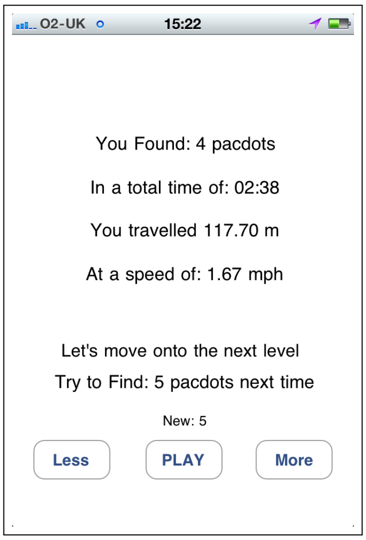


Figure 4.4: Collect the Pacdots statistics screenshot.

In Figure 4.4 the statistics screen for the game is presented. This screen provides basic information to the player, as well as giving them the option to override the basic level up/down algorithm. At the end of each game, whether the player has won or lost the preceding game, they have the option to set the difficulty level of their next game by pressing the ‘Less’ or ‘More’ buttons.

4.5.1.4 Escape the Ghost

The second of the mini-games also follows the Pac-Man theme, this time with a simplified game mechanic. In this game, the goal of the player is to avoid a chasing ghost for a predefined period of time. Unlike the previous game, in this game the ghost actively pursues the player, moving towards their GPS location. The player must therefore move in the opposite direction from the ghost, changing direction and travelling at a greater speed than the ghost. When the player starts the game, the ghost is dynamically generated a predefined distance from the player. The time for which the player must avoid the ghost, and the speed at which the ghost can travel, are both dependent on the difficulty level, with higher levels representing faster ghosts and longer games.

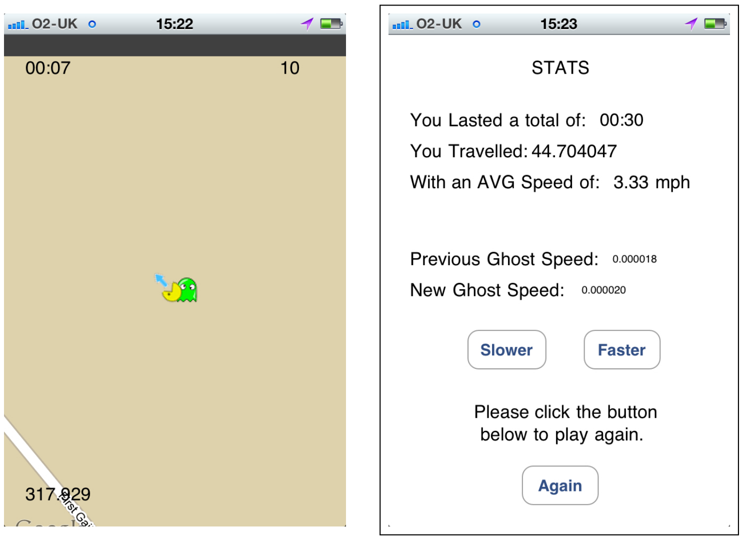


Figure 4.5: Escape the Ghost screenshot and statistics screen.

This game was designed primarily with high intensity training in mind, as the player is required to run at a high speed for a short period of time. The default game length is 20 seconds, building up to 40 seconds at the highest level. Thus, game lengths are approximately what would be expected within high-intensity interval training [212]. A series of mini-game plays done at a high intensity could form the basis of an effective interval program.

Much like the Collect the Pacdots mini-game, at the end of each mini-game the player is provided with a statistics screen. This provides basic information on performance, as well as allowing for difficulty level customisation.

4.5.2 Design Summary

On the advice of the P.E. teacher, the mini-games specifically focus on physical activity, building the game elements on top of the type of movement to be facilitated. Simple game mechanics (collecting items / escaping a NPC) were chosen due to the simple translation from PA to game mechanic, as well as the suitability of simple mechanics for location-aware games [133]. The Pac-Man theme was an abstract choice as it fits within the selected mechanics (collecting and avoiding). However, through a 'skinning' process, all game avatars and items could be changed to suit the preferences of the user. Due to the lack of feedback on content themes, it was decided to proceed with a recognisable character, and refine the content based on user evaluation feedback. As this first development phase focused on an early high-fidelity prototype, many of the design considerations recommended by the literature were neglected, as these would be considered during a later phase once the general suitability of the game had been established.

4.5.3 Prototype 1 End-User Evaluation

This section discusses the first empirical evaluation of the prototype exergame. It can be thought of as a 'proof of concept', with the goal of establish the high-level effectiveness of the game. The purpose was to assess how well it met the requirements of the end-users, both the players from a theme and content point of view, and the teachers in terms of the requirements outlined in Section 4.4.4. Having completed two bug finding evaluations at a University of Edinburgh symposium[1] the process moved onto testing with the target audience. The aims of the evaluation were as follows:

1. Establish how enjoyable the game was to play;
   (a) Does this differ based on the gender or gaming background of the participant?
2. Establish how physically intensive the game was;
   (a) Were the games physically demanding to participants from the target audience?
   (b) Was the type of exercise facilitated appropriate?
3. Establish whether the system could feasibly be implemented within a P.E. class as a physical activity intervention;
   (a) Were there any logistical requirements that had not been considered?
   (b) Were safety concerns realised or properly addressed?

In order to answer these questions, 25 participants aged 12-15 years old were recruited from a local high school. The children came from two different classes: one a Computing class, the other a P.E. class. Informed consent from both the participant and their guardian was obtained prior to the evaluation. The evaluation consisted of two separate 3 hour sessions (each participant attended only one session), during which time the children were: (i) briefed on the system; (ii) filled in a pre-evaluation background questionnaire; (iii) given a demonstration on how the game worked; (iv) given 30 minutes of free time to play both of the mini-games; (v) filled in a post-evaluation experience questionnaire; and (vi) participated in a short post-evaluation focus group

[1] http://sites.ace.ed.ac.uk/peariameter/

discussion. Two teachers, one a P.E. teacher, were also present during the evaluation to aid in assessing the suitability of the game for a school context and for promoting physical activity. The data gathered came from the expert observations, pre- and post-evaluation questionnaires, the post-evaluation focus group, and in-game log-files which showed how the players' self-reported enjoyment and exertion changed with time, as well as statistics on in-game performance (such as distance travelled, average speed, and success levels).

The full details of the study are presented in [121]. This section highlights the key results and the subsequent discussion which progressed the development of the prototype system.

1. Establish how enjoyable the game was to play. Overall the participants rated their enjoyment of the game highly, with the median and mode reported as 4.0 (on a 5 points scale, mean = 4.08, sd = 0.493). 84% of the participants stated that they wanted to play the game again in their P.E. class. A detailed analysis of the in-game log-files highlighted that the participants generally reported a high enjoyment from the beginning of the session, which was generally maintained or slightly increased throughout the session. Although males (median and mode = 4.0, mean = 4.27, sd = 0.46) and females (median and mode = 4.0, mean = 3.90, sd = 0.32) both liked the game, a Mann-Whitney U test indicated boys enjoyed the game significantly more than females (U = 44.0, Z = -2.303, $p < 0.05$, $r = 0.46$), with r indicating a large effect size. The results of a Kruskal Wallis test showed that there was no significant difference in enjoyment between groups with different gaming backgrounds ($H(3) = 2.181$, $p = 0.581$).

2. Establish how physically intensive the game was. Overall the participants rated their level of physical exertion whilst playing the game highly (median and mode = 4.0, mean = 3.76, sd = 0.52), with the P.E teacher stating that the children were "working as hard, if not more so" in comparison to their traditional P.E. lesson. A Mann-Whitney U found no significant difference in reported exertion by gender (U = 69.0, Z = -0.408, $p = 0.867$) while a Kruskal Wallis test detected no effect based on the gaming background of the participant ($H(3) = 2.347$, $p = 0.582$). An analysis of the Escape the Ghost log-files showed that the mini-game encouraged a gradual build up of exertion across the session and that the average speed (5.98 mph, sd = 1.17) of a player during the mini-game can be classed as vigorous intensity exercise [69, 151].

3. Could the system feasibly be implemented within a P.E. class as a physical activity intervention? Based on the success of the trial session, the mini-games appeared to be well suited to the type of activity expected from a school P.E. class, as well as the contextual constraints associated with a school-based context. The observing P.E teacher stated that the general intensity level of the mini-games was appropriately set for the target audience and the children found the game to be enjoyable, showing more enthusiasm than she generally observes in class.

4. Were there any logistical or safety requirements not considered? Based on observations, the children safely enjoyed the game during the session. There appeared to be no logistical problems.

5. Other interesting findings. As was highlighted in the research questions within Chapter One, one purpose of this research was to gain a better understanding of the exergame experience. Although the primary purpose of this study was to validate the prototype exergame, the evaluation served as a means to begin investigating the exergame experience. Through an analysis of the log-files, the point-biserial correlation coefficient was used to establish that there was no significant link between winning or losing a mini-game and the level of enjoyment of the participant ($r_{pb} = +0.17$, $t = +1.71$, df $= 104$), highlighting that players who regularly lost the mini-games suffered no down turn in enjoyment rating.

Another finding relates to participants' willingness to customise the difficulty level of the games, with the players choosing to override default difficulty changes 66% of the time. In [121], a number of interesting case studies are highlighted, showing how different players used the custom difficulty feature to suit their needs, from providing greater challenge to guaranteeing in-game success.

A final interesting observation from the session was the preference towards the Escape the Ghost game, with 22 of the 25 participants (88%) stating that they preferred the game. Among the reasons given for the preference, John stated, "It was more exciting", Mel stated, "You got more exercise", and on a related note, Mark observed, "in Escape the Ghost you have to run about, but in Collect the Pacdots you are just walking". 10 of the 22 (45%) participants that preferred the Escape the Ghosts game explicitly stated that their preference came from the fact that they were encouraged to exercise more.

4.5.4 Summary

Generally, the early prototype could be classed as a success. The results showed that between the two mini-games, players experienced both enjoyment and physical activity to the degree hoped for. It was also reassuring that the P.E. teacher remarked positively on both the level of exercise and enthusiasm of the pupils, and the way the system seamlessly fits into the P.E. class.

Looking in more depth at the results, there were aspects which required specific consideration during the subsequent development process. First of all, the significantly higher enjoyment experienced by males was somewhat undesirable given that females were also consulted throughout the development process. However, as the females still generally enjoyed the experience, a complete change to the game was not required during the next iteration. Qualitative feedback suggested that more 'gender neutral' themes could address this issue, with ghosts in particular perceived as more suitable for a male audience.

The second matter of interest was the strong preference towards the Escape the Ghost game. Had iFitQuest been visualised as a single mini-game, the Collect the Pacdots game would be removed from further evaluation. Many of those that provided a reason for the preference highlighted the fact that Escape the Ghost facilitated a greater amount of exercise. Over the course of a longer session, or a prolonged intervention, it is important to maintain a balance. Collect the Pacdots, through its more flexible design, represented a game that could be more appealing to those with very low starting fitness, or those tired or bored with other games. Development therefore moved forward with the goal of extending the suite, such that there was a greater variety in the type of games and physical activity being targeted. Of interest, was the preference of players towards a more physically demanding game and the positive reaction to a more 'simple' game mechanic. The way in which players migrated towards certain mini-games was the focus of both prolonged usage principal evaluations, discussed within Chapter Six and Seven.

Finally, there were interesting findings relating to how the players reacted to success and failure within the mini-games and the way that difficulty levels were customised to suit the participants' needs. Although tentative, these findings can be brought back to the research questions on the way in which the background of the participants affects their in-game behaviour and experience [121].

While the results in this study provided more questions than answers, supporting the need for further development and evaluation, they did highlight some important design considerations to bring forth to the next stage of the development process. First of all, the concept of custom difficulty setting was supported, with the majority of the participants willing to sensibly use the feature to exercise at an appropriate level. The importance of a flexible gaming environment in order to facilitate and support disparate emergent behaviour was established, with different players showing a variety of game selection and difficulty setting behaviours. Related to the research questions within Chapter One, it is important that players are afforded flexibility over their experience. Thus, while the literature may support *Marginal Challenge* [32, 203], iFitQuest was designed to support customisation of that setting to see how different players use the feature and how that can be linked to their background, in particular whether their self-efficacy levels influenced their behaviour.

Based on the first prototype evaluation, the following findings influenced future design:

1. **Custom Challenge** - Allow players the ability to set their own difficulty level, while providing support on recommended settings.

2. **Open Environment** - Linked to the concept of *Free-Play* [32, 203], players should be provided with an open gaming environment such that they have flexibility to influence their exergame experience. This is related not only to the custom difficulty levels, but also goal setting and game selection.

3. **Game Skin** - With the game skin more suited to a male demographic, the next iteration aimed for a more gender neutral selection.

4. **Simplicity** - With the simplicity of Escape the Ghost supporting higher intensity physical activity, the idea of simple mechanics for more demanding mini-games was considered.

4.6 Prototype 2

Building upon the findings of the first prototype evaluation, the next phase of the development involved extending the suite to provide greater variety, and slightly altering the initial two mini-games in order to help them appeal to a wider audience.

4.6.1 Re-Skinning

It was decided that the suite should be re-skinned with a farmyard theme. The choice of theme was inspired by the recent popularity of games such as FarmVille (with around 80 000 000 players worldwide in 2010) and the fact the game was particularly popular with both genders [84]. A small informal focus group that followed the preliminary evaluation also confirmed that the theme was more appealing to the players. A farmyard theme could also feasibly replace the initial two mini-games without fundamental changes to the game mechanics, as well as provide inspiration for additional mini-games for the suite.

4.6.2 Mini-Games 1 & 2

Figure 4.6: Re-skinned games, Collect the Coins and Escape the Wolf.

Figure 4.6 shows the re-skinned Collect the Pacdots (now *Collect the Coins*) and Escape the Ghost (*Escape the Wolf*) mini-games. As well as alterations to the visuals, the Collect the Coins game was adapted so that the coins were larger than the pacdots, and as such the player needed to be less specific about their location in order to collect an item. This alteration was to encourage less emphasis on looking at the device, in the hope that it would raise the popularity of the game and increase its ability to promote more intense physical activity. Vibro-tactile output when a coin is collected (phone vibration) and audio output confirm to the player that they have collected a coin. To this end, players can orientate themselves and then run towards a coin, only stopping once an output is heard, in contrast to slowly walking while fixated on the device as was observed during the previous evaluation.

Figure 4.7: Return the Sheep screenshot.

4.6.3 Mini-Game 3 - Return the Sheep

The third mini-game to be added to the suite was titled *Return the Sheep*. In this game, the player must collect a sheep and return it to its pen before the time runs out, see Figure 4.7. This game took inspiration from *Shuttle Runs*, an effective form of training taught in P.E. classes, in which the participant is required to run repeatedly between two set points. In order to avoid the more specific movements required in the Collect the Pacdots mini-game, the zone which stipulates when an item is collected was made larger, with both the sheep and the pen larger than a pacdot was in the initial prototype. In order to add a further mechanic to the game, the sheep itself was made to move (although its movement was limited to a set zone to stop it getting too far away). Thus, the successful concept of chasing was re-used. Again, 10 levels of difficulty were implemented, with the difficulty dictating the speed at which the sheep can move, the starting distance between sheep and pen, and the time allotted to complete the task.

4.6.4 Mini-Game 4 - Follow the Chicken

The fourth mini-game added to the suite was called *Follow the Chicken*, with this game reversing the concept of the Escape the Wolf game. Rather than having to run away from an animal, in this game the player is required to follow a chicken for a predefined period of time, see Figure 4.8. If the player lets the chicken get too far away, the game is lost. Follow the Chicken builds upon the successful concept of chasing used within Escape the Wolf. However, as the chicken travels more slowly than the wolf, and the game times are longer (between 30 and 50 seconds), Follow the Chicken was designed to generally facilitate moderate intensity physical activity. Again, difficulty could be customised by altering the speed at which the chicken moves and the duration of the game.

Figure 4.8: Follow the Chicken screenshot.

4.6.5 Mini-Game 5 - Visit the Fields

The fifth and final mini-game added to the suite during this iteration was titled *Visit the Fields*. In this game, the player is required to travel to three different locations in an order defined using the colours of a traffic light (a concept regularly used within school P.E. classes). As can be seen in Figure 4.9, three fields are generated around the starting location of the player. The player must then run to the green field, followed by the amber and then the red, within a predefined period of time. The locations of the coloured fields are randomly generated around the player, such that there is always a field in front of, in-line with, and behind them. The colour of the fields is also random so that the player never knows which direction they will be running in first. This game was designed to encourage a variety of physical activity, with higher intensity running required (between fields) as well as directional changes and sustained effort. This game is another hybrid of sorts, mixing elements of Escape the Wolf and Collect the Coins. The player is required to visit certain locations, but with a greater urgency due to a time limit. The large field sizes were designed to move emphasis away from the visual outputs, in order to allow for more intense physical activity. Like all mini-games, there were 10 levels of difficulty, controlling the time allotted to the player and the distances between the fields.

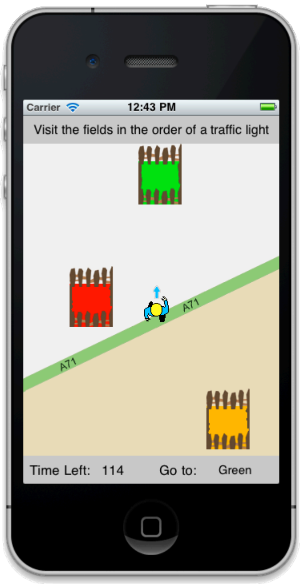


Figure 4.9: Visit the Fields screenshot.

4.6.6 Prototype 2 End-User Evaluation

The first prototype evaluation served as a proof of concept, confirming that the initial mini-games could be both physically demanding and enjoyable. The second evaluation aimed to build upon these earlier findings by assessing the changes to the original mini-games, as well as the suitability of the new mini-games in the suite. As a secondary aim, this evaluation served as a taster to both the children and the teacher as to how the system could be used within a P.E. class. It was a hope that the playthrough could persuade both the teacher and the children to take part in an additional, prolonged evaluation that would serve as one of the principal evaluations of this thesis. The second prototype evaluation therefore had the following aims:

1. Establish how enjoyable the games were to play;
   (a) Does this differ based on the gender or gaming background of the participant?
   (b) Are the new mini-games enjoyable?
   (c) How do people feel about the suite of games?
2. Establish how physically intensive the game was;
   (a) Are the three new mini-games valid from a physical activity perspective?
3. Persuade the class to take part in a longer term evaluation.

In order to answer these questions, a small-scale school-based evaluation was conducted with 11 children (representing one whole P.E. class). Of the 11 participants,

Figure 4.10: Children evaluating the second prototype of iFitQuest.

5 were male and 6 female, all aged either 14 or 15 years old. As the children came from a mandatory P.E. class[2], there was no preselection in terms of exercise background. Thus, the participants represented a range of fitnesses, with self-rating of fitness ranging between 5 and 9 (scale 1 - 10, median = 7.0, mode = 6.0, mean = 7.2). The evaluation lasted a total of 2 hours, with the gameplay designed to mirror that of how the system would be implemented into a school context, i.e. children arrived, got changed, and then played the game for the same time they would do a traditional P.E. lesson. The remaining hour was spent completing post-evaluation questionnaires with individual informal interviews used to clarify answers. The data was again supplemented by an expert observation (the class P.E. teacher, a different teacher from the prototype 1 evaluation) and post-session expert interview, as well as in-game log-files.

One shortcoming of this evaluation was that due to adverse weather conditions, the evaluation ended sooner that planned. The result was that only four of the five mini-games were played. As is customary with outdoor P.E. classes, if the teacher decides that the weather is too inclement for the class to proceed safely, the lesson is finished early. As a result, none of the children managed to play the Return the Sheep game before the session was stopped. The results which follow only refer to the remaining four mini-games, with feedback for the final mini-game inferred, based on the findings from the other four mini-games. As a final note, two participants had to share a device due to hardware limitations. Rather than play together, they each evaluated the system individually over a shorter period of time than the other 9 participants.

[2]All school aged children in Scotland are required by law to participate in at least one P.E. class per week.

1. Establish how enjoyable the games were to play. Overall the participants enjoyed the experience, with the median and mode enjoyment score 7.0 (scale 1-10, mean - 7.1, sd = 2.43). All 11 of the participants stated that they would like to play the game again, opting their class into prolonged evaluation outlined in Chapter Six. In the post-evaluation questionnaire participants were asked to explain this decision. Six of the 11 participants stated that it was because they found the game enjoyable or fun. One participant additionally stated they found it better than their normal P.E. class, with 3 participants commenting on the fitness aspects. However, like the first prototype evaluation, a Mann-Whitney U test found that males enjoyed the game significantly more than females (U = 1.5, Z = -2.553, $p < 0.01$, r = 0.77). Again, r shows that the effect of gender on enjoyment was large, although both males (median and mode = 7.0, mean = 7.6, sd = 0.89) and females (median = 7.0, mode = 8.0, mean = 6.0, sd = 3.0) had generally positive opinions of the game. Due to the small sample size of the evaluation, these findings must be interpreted with caution [37]. It is difficult to establish from the qualitative data why this gender split occurred. All six females stated that they would like to play the game again within the context of a prolonged intervention. As the majority of females enjoyed the games, and importantly opted themselves into another evaluation using the same game, the development proceeded with the same general themes and style.

As another aim was to establish how the participants reacted to a suite of games, they were asked to rank in order of preference the four mini-games that they had played. Points were then awarded, with 4 points given to each participant's favourite game, 3 to their second, 2 to their third and 1 to their least favourite. Cumulatively across the 11 participants, the games were scored as follows:

1. Escape the Wolf - 35
2. Collect the Coins - 31
3. Visit the Fields - 23
4. Follow the Chicken - 21

These scores highlight that the original two mini-games were the most popular among the participants, although there was not a fundamentally large difference in the scores. All four of the mini-games were at least one participant's favourite game, and all but Escape the Wolf were someone's least favourite. This highlights the diversity in what participants enjoy, providing support for the concept of a suite of games and

Mini-Game	Average Game Length (s)	Average Speed (mph)	PA Intensity[3]	Range (mph)
Collect the Coins	22	3.11	Moderate	0.12 - 7.81
Escape the Wolf	9	4.52	Moderate	0.21 - 9.57
Visit the Fields	90	2.77	Light	1.72 - 3.82
Follow the Chicken	8	1.04	Light	0.07 - 2.62

Table 4.1: Breakdown of average speed, PA intensity category, and range of speed, for each of the four mini-games.

its ability to appeal to a wider demographic. Additionally, part of the reason for the lower scores of the two new mini-games could at least partially be attributed to 'teething' problems. Qualitative data showed that four of the six children that ranked Follow the Chicken as their least favourite, stated that they did so due to it being too hard; while all three of those that ranked Visit the Fields the lowest, gave the reason as in-game bugs.

2. Establish how physically intensive the game was. In order to establish how physically intense the games were, both the expert observer and the in-game log-files were consulted.

An analysis of the log-files showed the average speed at which the participants played each of the mini-games. While not an in depth account (it shows only the average speed across the mini-game, rather than a second by second overview), it allows for general inferences on how each mini-game facilitated physical activity.

As is shown in Table 4.1, the four mini-games generally support moderate and light intensity exercise, although both the Collect the Coins and Escape the Wolf game supported vigorous intensity exercise (as is shown by the range). The light intensity average speed of the Follow the Chicken game can be partially attributed to the difficulty of the game. The average length of a game was only 8 seconds, meaning that players did not have much time to work out which direction to run, and build up speed. It was positive to note that the mini-games supported a range of intensities, providing allowances for different levels of fitness and the current fatigue of the player.

[3]Throughout this thesis, when establishing the intensity of physical activity performed by the iFitQuest players, guidelines outlined by the Centre for Disease Control are utilised: http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Intensity_table_2_1.pdf. These guidelines provide a 'rule of thumb' approach to converting between speed in mph and physical activity intensity. By using the mph thresholds for the different intensities of physical activity, it is possible to categorise mini-games based on the average speed that a player travels whilst playing that game. This allows for general conclusions to be drawn on the ability of iFitQuest to promote a range of physical activity intensities. Within one of the prolonged iFitQuest evaluations (outlined in Chapter Seven), a more rigorous and well validated method of establishing physical activity intensity is explored.

Additionally, the expert P.E. teacher stated during the post-evaluation interview that she was happy with the level of intensity observed during the session, and that based on her observations, the children would get enough physical activity whilst playing the game to justify its inclusion within a P.E. class. The children themselves had a mixed reaction to the amount of physical activity they received, with the the median and modal self-reported exertion at 5.0 (scale 1-10, mean = 5.54, sd = 1.753, range = 3-8). As with the previous evaluation, a Mann-Whitney U detected no difference in exertion by gender (U = 9.0, Z = -1.135, p = 0.292).

3. Persuade the class to take part in a longer term evaluation. All 11 members of the class voted that they would like to use the game as part of a prolonged intervention, and the P.E. teacher was positive about the type and intensity of the exercise facilitated by the game. Thus, the group was successfully recruited to use the final version of iFitQuest as part of a medium-length school-based PA intervention. Their use of the system is outlined and discussed within Chapter Six.

4. Additional Findings Central to the research questions of this thesis, and supported by the tentative findings from the initial prototype evaluation, one aim of this research was to investigate self-efficacy, and its role during the exergame experience. Therefore, all 11 participants in this evaluation took part in a pre-evaluation exercise self-efficacy assessment, using an instrument developed by Pender [159][4] [5], see also [162]. Within the context of this prototype evaluation, the purpose of applying the instrument was to investigate its feasibility for the target demographic. All 11 of the participants answered the questionnaire without issue and thus the instrument was brought forth in its current form. At this stage no attempt was made to investigate the role of self-efficacy within this study, due to the implicit need of time, i.e. prolonged use of the system is required to see the emergent behaviour required.

4.6.7 Summary

The goal of this phase was to extend the suite of mini-games, in order to provide more variety to the players as well as targeting more aspects of physical activity. By developing three additional mini-games, and modifying the two original mini-games, the goal was to build upon the success of the original prototype. Looking at the results from this second evaluation, it was possible to conclude that the user-centred

[4]Instrument retrieved from Pender's institutional webpage, although the files are now no longer available. http://www.nursing.umich.edu/faculty/penderinstruments/researchinstruments.html

[5]Modified and provided by Dr. Samantha Fawkner.

design process was successful in creating enjoyable and physically demanding games, which fit within a school context.

By providing greater variety to the suite, the system successfully appealed to a wide demographic, with all four of the mini-games providing enjoyment to particular players. This provides evidence supporting the concept of a suite of mini-games. By providing greater depth and variety, the chances that at least one element of the exergame will appeal to a player is increased. The suite allows for a variety in both the gameplay and the intensity of exercise supported.

Of significance was that fact males rated the game significantly higher for enjoyment. Although, again, the females generally enjoyed the experience, their scores were lower than their male counterparts. While the results must be carefully interpreted, it appeared that the change in theme between Pac-Man and farmyard did not help balance the interest levels. As all of the children in the study agreed to use the game again as part of a prolonged evaluation, it would be unnecessary to considerably modify the theme of the game again. Thus, the farmyard theme and the five current mini-games (with further refinement) remained in the suite. As two consecutive evaluations highlighted females had lower enjoyment, it raised the question as to whether this type of exergame could indeed ever have the same appeal to the demographic, in whatever form it comes. The evaluations outlined within Chapter Six and Seven further consider the role of gender.

Although only four of the five mini-games were evaluated, this study served to validate the mini-game approach.

4.7 Summary & Conclusions

Within this chapter, the first three phases of the development approach have been outlined. Utilising a U-CD methodology, driven by rapid prototype development and evaluation, a prototype suite of mini-games was developed and evaluated. All three phases of the development process served to establish the design requirements for such a system. During the later two phases of the development, working high-fidelity prototypes were developed and evaluated in-situ within a school context. The findings during each iteration validated the mini-game approach, and served to further refine and improve the exergame. In total, 36 children from the target demographic played some form of the game within their school P.E. class, providing feedback and suggestions which influenced future design iterations.

During the two prototype evaluations, initial evidence to support the research questions was gathered. Although the systems were only tested on a one-off basis, there was evidence that a mobile location-aware exergame can be successfully integrated into a school-context, effectively facilitating enjoyable physical activity for an adolescent audience. Going beyond this, tentative evidence was found which contributed towards the focus of this research, the desire for a deeper understanding of the exergame experience.

Finally, the process outlined within this chapter contributes towards the fields understanding of the design process involved with exergame development. A U-CD approach was successfully utilised to provide valuable feedback from target players, school teachers and PA experts. On a methodological level, the suitability of adopting focus groups during early requirements gathering phases must be questioned, in particular for this demographic. As Davis et al. point out, when designing games, "Focus groups can be useful for concept generation in the initial stages of a project or for obtaining a better general understanding of a problem space in some circumstances. However, they are poor at providing specific, actionable data" [45]. In the case of this development, this was found to be true, with the results further confounded by the participants' lack of exergame experience. Davis et al. go on to state, "Judgments about the value of a concept can be dramatically different from judgments of the concept's practical implementation in a game". This is especially true for pervasive exergames, where the idea on paper can be drastically different to the implemented game, played out on the real world using mobile devices. In hindsight, while the focus groups were useful practice for working with an adolescent audience, and highlighting some of the behavioural and social issues inherent in the demographic, as a means to generate ideas for a novel concept such as an exergame, it was left primarily to the developers to establish the themes and content for the early prototypes. Thus, future developers should consider what their primary aim is when adopting focus groups during exergame development, because until exergames become more commonly played and less of a novel concept, adolescent children will probably struggle with idea and concept generation.

The next chapter serves to outline the final exergame system, designed based on the three development iterations outlined within this chapter. The two longitudinal evaluations, representing the final phase of the last iteration of this development approach, are then outlined in Chapter Six and Chapter Seven. Table 4.2 provides a summary of the four main development phases undertaken in order to develop the iFitQuest system and answer the research questions of this thesis.

Table 4.2: The main development phases undertaken during the development of iFitQuest.

Dev. Phase	Purpose	Technique	Findings
1. Early requirements gathering.	To establish the system requirements of the target users. The logistical / exercise requirements of P.E teachers and content / theme requirements of adolescent players.	1. Expert Interview. 2. Game Enjoyment Focus Group. 3. Exergame Play Focus Group.	Eight design requirements to guide the development of the system were established (Section 4.4.4). The feasibility of focus groups as a methodology for this type of development was also questioned.
2. Initial two mini-game prototype.	To validate the initial two mini-games, confirming that they are enjoyable to play for the target audience, physically demanding, and appropriate to the context of a school P.E. class.	School-based evaluation with 25 children playing the game on a single occasion as part of their P.E. class. Outlined in Section 4.5.3.	The game was found to be both enjoyable and physically demanding, although changes were required to ensure the game was enjoyable for both males and females. Interesting findings on in-game behaviour, particularly with regard to the link between success and enjoyment, and the different uses of challenge levels were also made.
3. Five mini-game prototype.	To validate the additional three mini-games and the changes made to the initial two mini-games, as well as the concept of a suite.	School-based evaluation with 11 children playing the game on a single occasion as part of their P.E. class. Outlined in Section 4.6.6.	Four of the five games were validated, providing support to the theme and the concept of a suite of mini-games in order to provide diversity. The study highlighted once again a discrepancy between males' and females' enjoyment of the game.
Continued on next page			

Table 4.2 – continued from previous page

Dev.Phase	Purpose	Technique	Findings
4. Final system - iFitQuest.	To evaluate the final exergame, in order to answer the research questions of this PhD thesis.	Two school-based evaluations with a total of 26 children. Medium length evaluations with repeated use of the system. Studies outlined in Chapters Six and Seven.	Discussion and Findings in Chapter Eight.

CHAPTER 5

iFitQuest

The previous chapter outlined the first three iterations of the user-centred prototype driven development approach. Having developed and evaluated two high-fidelity prototypes with relative success, the final development iteration focused on refining the game to a standard such that it could be deployed for prolonged evaluation. This chapter begins by outlining the final changes that were made to the game, based on the results from the prior development iterations. The chapter concludes with the list of design requirements utilised within iFitQuest, established from both the literature and the three previous development iterations.

5.1 Final Changes

5.1.1 iFitQuest

The first stage in taking the game from a prototype to a final system was to move from a series of stand alone applications to a fully integrated system. While during the previous iterations mini-games had a consistent theme and style, each mini-game was implemented as an individual application. Integrating each mini-game into a central application, named iFitQuest, had a number of benefits. From a user experience perspective, players would no longer need to exit and restart applications in order to change the mini-game. Adding each mini-game to a central system would provide the user with greater continuity in the experience, and make it simpler to exert control over which mini-game to play. Additional game features could also be added, for example user profiles to store the gameplay progress of the player as well as more detailed behaviour tracking across the suite of mini-games. More details on the features added and the benefits of an overarching game are discussed in Section 5.1.3 − 5.1.5.

From an exergame perspective, the merits of developing iFitQuest as a suite of mini-games was outlined within Chapter Four. By integrating each mini-game into an overarching game, play sessions were designed to mirror an interval training approach, with players' performing short period of physical activity (i.e. playing a mini-game) interleaved with period of rest or light intensity physical activity (i.e. returning to the main menu between mini-games, or viewing user statistics).

5.1.2 Mystery Games

The results from the second prototype evaluation highlighted that the mini-games successfully facilitated light and moderate intensity exercise (see Table 4.1 on Page 68). Two of the mini-games also had ranges into the vigorous intensity category, highlighting the potential for such games to facilitate higher intensity physical activity. It was thus desirable to extend the suite with additional mini-games more suited to higher intensity physical activity. Three new mini-games were devised, titled the *Mystery Games*.

Top Speed - The player has 20 seconds to reach as fast a speed as possible. The goal of the game is to beat their previous personal best on the game.

Average Speed - The player has 30 seconds to reach as high an average speed as possible. Again, the player is rewarded for beating their own personal best.

Furthest Distance - The player has 40 seconds to run as far as possible. Like the above, this player is aiming to run further in the allotted than their own previous best.

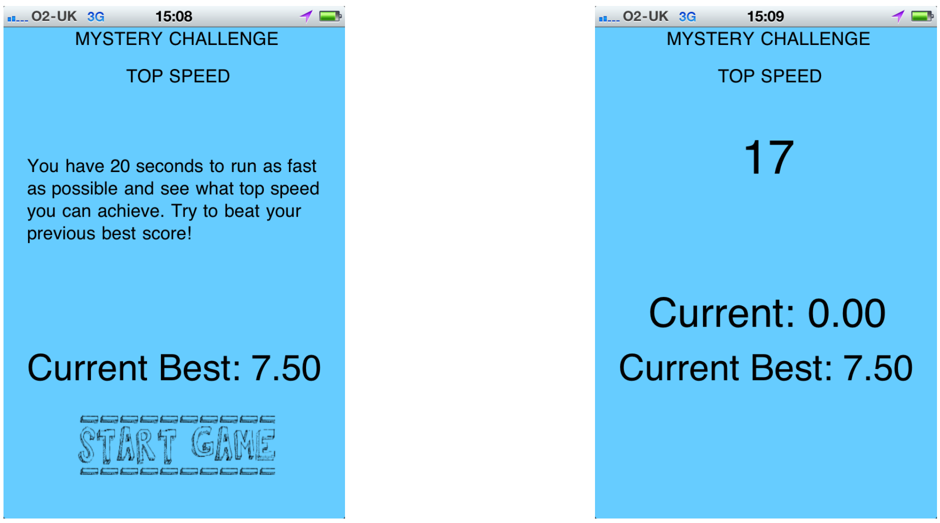


Figure 5.1: The Top Speed Mystery Game interface, with start screen (left) and the in-game screen (right) showing time left, current score and previous best score.

Simple mechanics and interface design was adopted in the hope that the mini-games would more readily facilitate MVPA. See Figure 5.1 for a sample of the interface design.

An important aspect of these mini-games is the notion of Personal Bests (PBs), a concept common within PA. The player is competing against themselves, in the sense that during each mystery game they are challenged to improve upon their own previous scores. The way in which this can be utilised within goal setting is discussed within Table 8.1 on Page 232.

5.1.3 Points

A further addition to the game was the inclusion of a points system. Players are given the opportunity to earn between 0 and 10 points when playing each mini-game. These points are then accumulated, both across the current session (all of the mini-games played that day) and cumulatively across the entire evaluation period.

In earlier versions of iFitQuest players could infer some details of their performance based on the outcome of the game (win or lose), and the post-game statistics (such as speed or distance travelled). One advantage of the points system is that it provides a valuable form of feedback, providing the player with an easily understandable means of measuring their performance [165]. Rather than having to remember and understand the post-game statistics, the player can get an overview of performance level from the number of points they have earned.

As well as providing feedback, the points system adheres to the exergame design requirements of *Micro-Goals* [32] (i.e. earn as many points as possible for a mini-game), and adding to the players' personal awareness [32, 39]

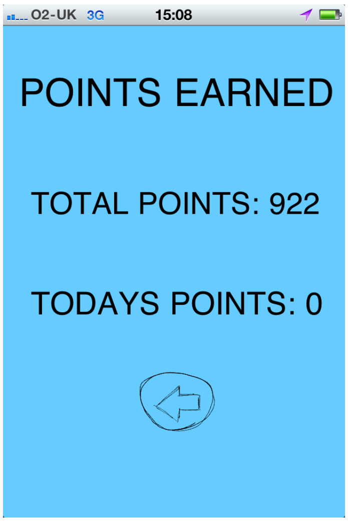
Another advantage of the points system is the addition of a running points total across the duration of the evaluation. This provides the player with a *Macro-Goal*, a longer term goal whilst playing the game. This helps iFitQuest meet the design requirement outlined during the focus groups, where participants emphasised the need for an "overall point" to the game.

Additionally, according to Yee in his work on player motivations, simply accumulating an in-game resource can provide motivation to a player [232]. Therefore, as an additional benefit to the points system, even those that have no interest in using points to compete with other players or measure their own performance, could be motivated by the simple act of accumulating points. Thus it should provide further motivation and aid in the sustainability of the system. Within exergames, this type of virtual incentive has been found to be an effective motivator and aid in enjoyment

[23]. During the second focus group of the development process, having tested commercial exergames, the participants identified a points system as a possibly useful game feature.

Essential with the addition of the points system was that the game remained designed for flexibility. Where as some exergames set the player definitive goals [115] or emphasise the aspect of competition [4, 115, 163], within iFitQuest the points system is left open to interpretation. The player is free to ignore the points they have earned and their implication for performance tracking or competition. The player is free to set their own goals, points targets, or compete with their peers. This flexibility ensures that the player has more control over their exergame experience allowing for the more detailed investigation required in order to answer the research questions of this thesis.

In Figure 5.2 the main points screen is shown along with a view of the mini-game completion screen, showing the number of points the participant has earned.



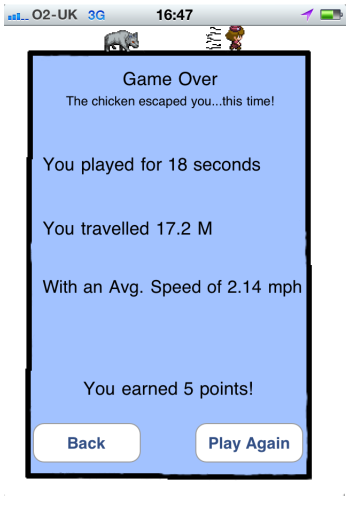


Figure 5.2: The points statistics screen (left) and the screen shown at the end of a mini-game showing points earned (right).

Within the final iFitQuest system there is a component dedicated to calculating the points to be awarded to the player, see the architecture diagram Figure 5.8 on Page 87. The points calculator contains a number of simple algorithms, which for each mini-game look at the player's current performance, previous performances, and the level of game difficulty, in order to award the appropriate points. The algorithms consider the average speed of the player (rewarding faster speeds relative to prior performance), the distance they travelled (rewarding greater distance relative to prior performance), what difficulty level they were playing on, and whether they won or lost the mini-game. The algorithms also cater for players trying to 'game' the system, rewarding zero points when the player makes no effort to move. While the algorithms take into account the difficulty level of the mini-game, the main considerations for earning points are average speed and distance. This helps iFitQuest meet the design requirement of Fair Play [32], as players are not heavily penalised just because they cannot reach the highest difficulty levels. Instead they are rewarded primarily for improving their own performance levels. A psuedocode version of the algorithm is shown in Algorithm 1.

```
Data: gameDistance, avgGameDistance, gameSpeed, avgGameSpeed,
      difficultyLevel, gameOutcome
Result: The number of points earned by the player (between 0 and 10)
pointsEarned = 1;
if gameDistance ≤ 5.0 metres then
    pointsEarned = 0;
else
    if gameOutcome is Win then
        pointsEarned = pointsEarned + 3;
    end
    if gameDistance ≥ avgGameDistance then
        pointsEarned = pointsEarned + 1;
    end
    if gameSpeed ≥ avgGameSpeed then
        pointsEarned = pointsEarned + 2;
    end
    if difficultyLevel ≤ 3 then
        pointsEarned = pointsEarned + 1;
    else if difficultyLevel ≤ 6 then
        pointsEarned = pointsEarned + 2;
    else
        pointsEarned = pointsEarned + 3;
    end
end
return pointsEarned
```

Algorithm 1: Algorithm to calculate points earned for the 5 core mini-games.

5.1.4 Leaderboard

Building upon the points system, a web-based leaderboard was added to the game. The leaderboard shows the total number of points each player in the class has achieved, displayed as a character running on a map, a common approach within exergames [39, 71, 163]. Figure 5.3 shows an example of the web-based leaderboard.

Figure 5.3: Example output of the web-based iFitQuest leaderboard.

A leaderboard is a method of encouraging competition, with the performance of the player being directly compared to their classroom peers. While competition is a common incentive within many forms of physical activity, on a psychological level it is not desirable for everyone. By Nicholls' definition, a competition evokes *ego-involved* motivations, which can have strong implications on performance depending on the background of the player. For example, individuals with high perceived ability often choose to undertake easy tasks as they are worried about failure [152], an undesirable outcome for an exergame. Competition has also been found to negatively effect the intrinsic motivation of those of a non-competitive nature within exergames [191]. The potentially negative implications of competition on intrinsic motivation are well established [48, 169].

However, despite these potential problems, a leaderboard was included within iFitQuest. Competition has been effective in numerous exergame interventions [71, 115, 163, 193], with the use of competition explicitly outlined as an effective motivator [78].

By adding in a leaderboard, the system also helps meet the design requirement of *Social Play*, as interaction between players is encouraged [32, 39].

Finally, the implementation of the leaderboard was done so in a way to minimise its potentially negative implications. As it is web-based rather than integrated directly into the game, during a session players can only see their own points and must make a special effort to establish the points of their peers. This prevents people from directly comparing performance unless they want to. On top of this, as points are awarded based on algorithms that utilise the previous performance of the player (see Algorithm 1), a player with low ability or fitness levels is not penalised in relation to more able peers. As all players have a level playing field, every person in the class should feasibly have a chance of earning the most points in the class. Thus, the way low performers can become demotivated in traditional competitive situations, as outlined by Nicholls, should be avoided [152].

The inclusion of a leaderboard also adds further depth to the research questions of this thesis. While in the long term it may not optimally increase intrinsic motivation in some players, it does allow for enquiry into how the background of the player influences reaction to the leaderboard and the way in which it can affect the exergame experience.

5.1.5 Game Manager

Another notable addition to the game was the development of a *Game Manager (GM).* The primary purpose of the GM is to provide some minor control over the mini-game selection process. The GM monitors what mini-games the player is selecting, and if they choose to play the same game 3 times in a row, the GM blocks them from playing that game until they have completed a Mystery Game.

While control and freedom are key elements to the design of iFitQuest (see Table 8.1 on Page 232), it was decided that a GM would prove beneficial in terms of facilitating PA. In the iFitQuest suite, each mini-game is designed to promote different intensities of exercise. Therefore, it is important that the players try a variety of mini-games during a session. The GM prevents players from continually reselecting the same mini-game, while only asserting a minor element of control over the experience. Figure 5.4 on Page 84 shows the main iFitQuest menu. The right image in Figure 5.4 shows the interface when the GM has blocked certain mini-games (there is no icon available).

A final feature of the GM is ensuring that mini-games are set to the correct difficulty level. By using knowledge of the player's previous performance, the GM sets the difficulty level dynamically for each mini-game selected in a session. For example, if the player won levels 1 through 9 of Collect the Coins during a previous session, the GM will make sure that during the next session, the game will begin at difficulty level 10.

5.1.6 Flexible Environment

As discussed, the notion of flexibility is an important consideration within iFitQuest. In order to better understand the exergame experience, it is important to encourage emergent behaviours from the players. Imposing particular constraints on the player could lead to artificial behaviour or prevent certain behaviours from occurring. As has been highlighted, self-efficacy can influence the goals people set themselves, their reaction to successes and failures, and the way in which their attitude and motivation changes with time. In order to understand the role of self-efficacy within exergames, it is implicit that a flexible platform is provided. This section highlights the way iFitQuest was designed to support a flexible experience.

First, despite the inclusion of a points system, and the associated leaderboard, there are no specifically assigned goals within iFitQuest. Players are free to select their own goals and work towards their own targets as desired. To this end, there are a number of different goals supported by iFitQuest, including but not limited to:

1. Winning the class leaderboard.
2. Improving mystery game personal bests.
3. Completing all games on difficulty level 10.
4. Gaining more points each successive week.
5. Making a self-set points target.
6. Beating a peer's score.
7. Playing as many mini-games as possible.

As has already been discussed, despite the inclusion of a GM, players are still provided with flexibility in terms of in-game selection. Although the GM will prevent a player playing the same mini-game more than 3 times simultaneously, it still allows a degree of flexibility. A player could still focus their efforts towards one particular mini-game, as long as they intersperse play with the Mystery Games. How a player organises their session is therefore down to the players' motivation and goals.

Another flexible aspect of the system is the way in which self-setting of difficulty is supported. Although iFitQuest has basic difficulty setting algorithms (which look at previously played difficulty level and success, see Algorithm 2), the players are free to override all system recommendations. A player is therefore free to move between the whole spectrum of difficulty levels, adopting strategies to suit their needs. This feature also provides further opportunities to understand the exergame experience, by investigating how different people utilise the feature to customise their experience.

Data: lastLevelWonAt, gameOutcome

Result: The initial, and subsequent difficulty level for a particular mini-game

```
//Set current mini-game difficulty to the difficulty level at which the
// player last won (not played)
currentLevel = lastLevelWonAt

//Set next mini-game difficulty based on the players success
if gameOutcome is Win then
    nextLevel = currentLevel + 1;
else
    nextLevel = currentLevel - 1;
end
if nextLevel == 11 then
    nextLevel = 10;
end
if nextLevel == 0 then
    nextLevel = 1;
end
return nextLevel
```

Algorithm 2: Algorithm to calculate starting and subsequent difficulty level for a mini-game.

5.2 System Overview

This section provides an overview of the final system. As the 5 mini-games developed for the second prototype were not significantly changed for the final system (minor background changes were made to address the issues highlighted in the previous chapter), they are not discussed in depth again. Table 5.1, provides a summary of all iFitQuest mini-games games.

Table 5.1: Overview of the eight iFitQuest mini-games.

Mini-Game	Concept	Difficulty Changes	Physical Activity Goal
Collect the Coins	The player must collect virtual coins as quickly as possible, without getting eaten by a patrolling wolf.	The number of coins to be collected and the distance between the coins.	**Mixed Intensity**. The player must run but with quick directional changes in order to collect the coins as quickly as possible.
Escape the Wolf	The player must escape a pursuing wolf for a predetermined length of time.	The speed of the wolf and the length of time to evade capture.	**MVPA**. The player must run at a fast pace in order to avoid capture.
Follow the Chicken	The player must chase a chicken for a predefined length of time.	The speed of the chicken and the length of time for which the player must pursue the chicken.	**MVPA**. The player must run fast in order to remain close to the chicken, but also show agility in order to quickly change direction.
Visit the Fields	The player must visit three coloured fields in a specific order.	The time allotted to visit the fields and the distance between fields.	**MVPA**. The player must run back and forth between the fields. Inspiration came from the traditional exercise used in P.E. classes called shuttle runs.
Return the Sheep	The player must catch a sheep and return it to its pen.	The time allotted to complete the game and the distance between the sheep and pen.	**MVPA**. Like Visit the Fields, this game takes inspiration from shuttle run training.
Mystery Game 1 - Top Speed	The player has 20 seconds to reach a top speed and beat their PB.	n/a	**Vigorous Intensity**. The player must run as fast as they can.
Mystery Game 2 Average Speed	The player has 30 seconds to maintain as high an average speed as possible, aiming to beat their PB.	n/a	**Mixed Intensity**. The player must run at a fast speed, but also be capable of maintaining their pace.

Continued on next page

Table 5.1 – continued from previous page

Mini-Game	Concept	Difficulty Changes	Training Targeted
Mystery Game 3 - Top Distance	The player has 40 seconds to run as far as they can, aiming to beat their PB.	n/a	**Mixed Intensity**. The player must maintain effort for 40 seconds.

Figure 5.4 shows the main menu of the system.

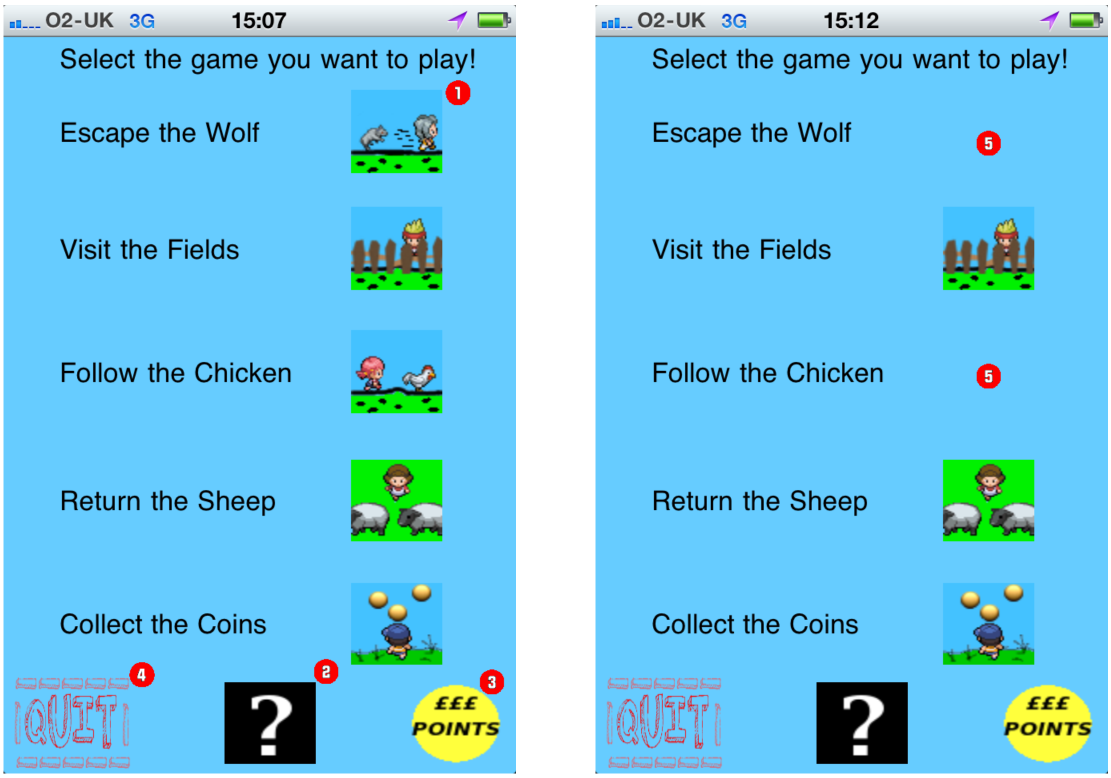


Figure 5.4: Main menu of iFitQuest.

(1) In order to select a mini-game, the player clicks on one of the mini-game icons.

(2) The mystery game is represented by a '?' icon.

(3) The points button takes the player to a new screen showing their total and session points, see Figure 5.2 on Page 77.

(4) Quit button which ends the exergame session.

(5) Shows the interface when a mini-game has been locked out by the Game Manager.

As well as constructing a main-menu for mini-game selection, a statistics screen was added to the game, in order to aid the player's personal awareness. The statistics screen displays the player's game history, including how many times they have played each mini-game, the number of games they have won and lost, how many points they have earned (in total and broken down by mini-game) as well as personal bests for each game. The statistics screen help raise personal awareness, an important consideration within exergame design (see Table 8.1 on Page 232), as well as helping with the continuity of iFitQuest across sessions by allowing players to revisit previous performance.

Figure 5.5: Example of the statistics screen.

As was discussed in Section 5.1.6 one feature of the final game is the ability to customise the mini-game difficulty levels. Figure 5.6 shows an example of the difficulty change screen shown at the end of a mini-game.

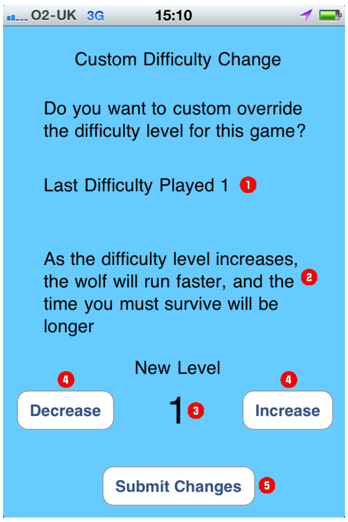


Figure 5.6: The difficulty change screen shown when someone chooses to replay a mini-game.

1. The player is shown the difficulty level from their last play of the mini-game.
2. They are given a description of how their changes influence the mini-game.
3. The currently selected level for the next playthrough.
4. Buttons to increase or decrease the difficulty level.
5. A button to confirm the changes and begin the next mini-game at the new difficulty level.

It should be noted that each mini-game has its own difficulty level, and changes made using the above method affect only that mini-game. The player is free to set separate difficulties for each different mini-game, rather than an overall iFitQuest difficulty. This allows for flexibility between games.

As was discussed in the previous chapter, self-reporting is a concept well used within P.E. classrooms. The P.E. expert consulted during the design of iFitQuest recommended utilising self-reporting within iFitQuest to help players reflect on their in-game behaviour. Self-reporting would also provide an opportunity for a better understanding of the exergame experience by tracking how players attitude changes over the course of a session. To fulfil this requirement, at random intervals throughout the session the player is shown a screen like the one shown in Figure 5.7, where they can provide real-time feedback on the session.

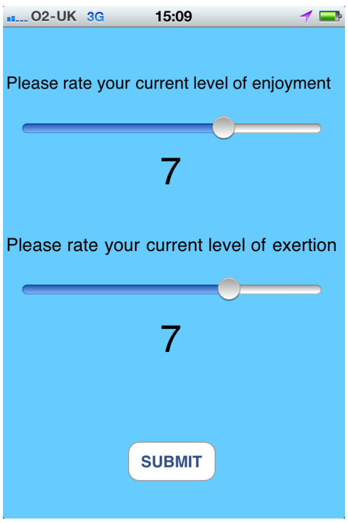


Figure 5.7: iFitQuest self-reporting screen.

5.2.1 Architecture

The architecture of the final iFitQuest system is shown in Figure 5.8. The primary interaction mechanism for users is the iPhone device, although the desktop computer is shown as a means to check the on-line leaderboard if desired.

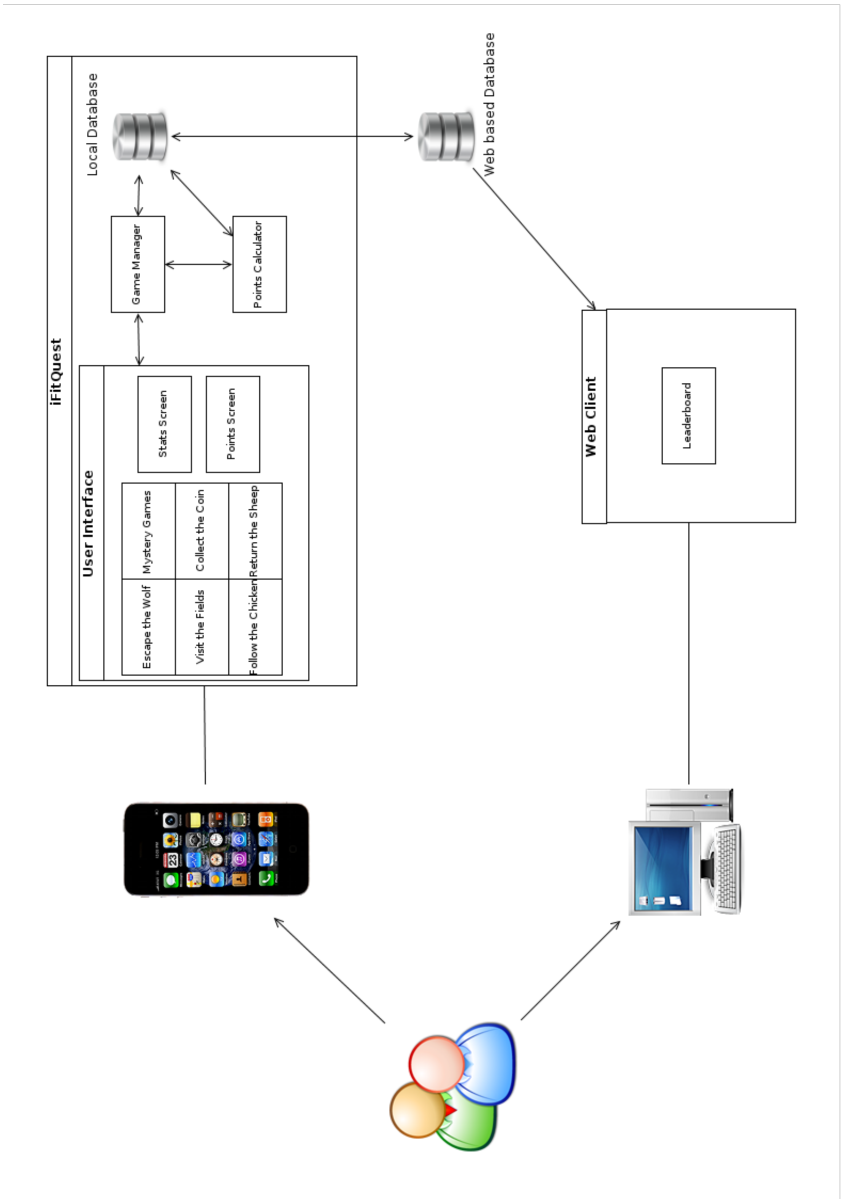


Figure 5.8: Architecture Diagram of the iFitQuest System.

As has been discussed, the iFitQuest game consists of the 5 original mini-games, and the additional 3 Mystery Games added during the final development iteration. Additionally, the player has access to a statistics screen and a points screen.

Working in the background, there are three primary elements. The GM discussed in Section 5.1.5 manages the gaming session, providing an element of control over mini-game selection and calculating how many points are awarded per mini-game. This is done in conjunction with a *Points Calculator*, which considers player performance history in order to award the correct points for each mini-game (see Algorithm 1 on Page 78).

The final element, not previously discussed, is the database. iFitQuest makes use of both a client-side and server-side database. Each player has their own user profile, used to store their iFitQuest history (such as in-game performances and points totals). Storing this on a server-side database was the logical decision as it mitigated the risk of losing data in the case of a hardware error as well as meaning players were not tied to specific devices. A local database was also used to store the data used during play. At the start of every session, the users' data is transferred to the local database on the device they are using. This minimises the need for communication between client and server, adding robustness to the system as well as minimising the cost of data communication.

5.2.2 Hardware

All iFitQuest evaluations were run using iPhone 4 devices. This was the newest iPhone device available at the prototype stage of the development process (2010). Although the Android operating system was also available, the iPhone was more popular for mobile applications, with over three times the market share [74] in terms of devices sold, and over five times as many applications available to consumers [6, 222]. Thus, the iPhone development environment was more refined and widely used, with a greater community of support. The iPhone was also widely regarded as the cutting edge in terms of mobile hardware, with the greatest processing power, and memory. It was therefore the logical choice to develop the system specifically for the iPhone.

As well as being the latest device at the time of the development, the iPhone 4 also had a number of benefits over earlier iPhone handsets. In comparison to its predecessor (the iPhone 3GS), the iPhone 4 has an increased battery life, and processing power, as well as a higher resolution display. While the iPhone 4 is a more powerful device, it is important to note that iFitQuest would still successfully run on an iPhone 3GS, as long as the appropriate software updates had been installed.

One important consideration with regards to the hardware used for iFitQuest is the need for a *magnetometer*, a piece of hardware which is used to measure magnetic fields and allows a device to be used as a compass. This is essential for iFitQuest, as it is necessary to know the direction of the user in order to accurately rotate the player's avatar on the screen. This allows for easier navigation between the player and the virtual game items. The first iPhone device to contain a magnetometer was the iPhone 3GS, and as such iFitQuest will not run successfully on earlier devices.

Although untested, all subsequent iPhone devices (the iPhone 4GS and the iPhone

5) contain the necessary hardware to successfully run iFitQuest.

5.2.3 Software

Due to the selection of the iPhone 4 as the device to be used for iFitQuest, the game was developed for the iOS platform, the native operating system to all Apple mobile devices.

Highlighted in the architecture diagram Figure 5.8, the majority of the iFitQuest system is local to the iPhone device, with the mobile client representing the majority of the complexity and thus development work. The iFitQuest mobile application was written in Objective-C, the object-oriented language used for all Apple development. Objective-C is a high level language based upon the C language. The *Cocoa* framework was utilised for the development. This makes use of the Model-View-Controller design pattern, allowing for an effective maintenance and development approach. The two core iOS frameworks, UIKit (adopted for interface design) and the Foundation framework (which provides a base layer of important classes, such as objects and arrays) were used for the development. In addition, iFitQuest makes use of a number of important iOS libraries:

1. Map Kit Framework - Allows maps to be embedded within the application and annotated with objects. This is used to display the player's avatars and all non-player items and characters.

2. Core Location Framework - Makes it possible to determine the location and heading associated with the device. This is used to get the location of the player, correctly display their avatar on the map, and determine their movement in the real world.

3. Quartz Core Framework - Framework that supports image processing. This is used to manipulate transitions between screen in the interface to increase the usability of the application.

In addition to the above, the iFitQuest client also contains support for a local database, to minimise communication with the server. To support this, sqlite3 a library that implements an SQL database engine was used.

The iFitQuest mobile client was developed for iOS version 4.3. iOS version 4 was shipped with the iPhone 4, and as such it was the logical choice to develop for this version of the software. iOS 4 is also compatible with the iPhone 3GS and the iPhone 3G (although this device lacks the necessary hardware as is explained above), and as such iFitQuest could be used with earlier version of the iPhone device if required. In terms of forward compatibility, iFitQuest is untested on either of the subsequently released iPhones. It is likely that new features implemented into the iOS software would mean that updates would be required to the code. In the future, it would be possible to update iFitQuest such that it runs on all devices from the the iPhone 3GS onwards.

Outwith the iPhone application, iFitQuest makes use of a *MySQL* database to store all of the users' details, with *php* scripts used for communication between the client and server. The MySQL database runs on the Heriot-Watt University servers, which have very little downtime and are well maintained. This is essential given the need to have one time access to the data on the server during each gaming session. The php scripts are called from the iPhone client to access the databases and return the required data.

5.3 Design Requirements

Outlined in Chapter Three, there exists a small body of work formalising design requirements for exergames. While these design requirements provide a good framework to build upon, they are not necessarily applicable for systems targeting in school use or an adolescent demographic. Much of the logic behind adopting a prototype driven user-centred design approach was to build upon this initial foundation by establishing new design requirements. This section serves to summarise the design requirements considered during the development of iFitQuest, both those from the literature and those established from the iFitQuest development process. Along with each requirement, a summary of how iFitQuest was implement with consideration for the requirement is given. Within the Source section of the table, EX refers to expert interview, FG1 refers to the initial round table focus group, and FG2 refers to the second focus group in which participants were given the opportunity to play exergames.

Table 5.2: The design requirements considered during the development of iFitQuest.

Design Req.	Meaning	Source	iFitQuest
1. Free Play	Provide the player with the ability to choose their path.	Req. Gathering Phase (FG1) [32] [203]	Players have freedom over which mini-games they wish to play and freedom to set their own challenges and goals.
2. Marginal Challenge	Challenge level set and altered at appropriate levels.	[7] [32] [203]	10 difficulty levels for each mini-game, each subsequent level representing a marginal increment in difficulty. Players can also custom set the difficulty levels.
3. Custom Challenge	While the game should support 'Marginal Challenge', the player should have the ability to custom choose their difficulty levels.	Prototype Evaluation 1	The player can custom override any automatic difficulty changes and are not confined to set increments. For each mini-game, they can play at whatever difficulty level they wish.
4. Social Play	Design the game to encourage social play.	[32][39][203]	The context of the intervention with multiple players at once allows for social interaction. The use of a points system and leaderboard encourage social interaction between participants.
5. Fair Play	Provide all players with a level playing field.	[32] [233]	Algorithms to award points compare the player to themselves. Player can set their own difficulty levels, and current levels are not shared with peers.
6. Personal Awareness	Provide players with the ability to see their activity levels.	Req. Gathering Phase (EX / FG1) [39]	Players are shown a statistics screen at the end of every mini-game. Overall intervention statistics (with personal histories) are available from the main-menu. The points system adds a simple method of understanding progress.
7. Quick Start	The game should be pick up and play and contain minimal distractions (set-up / loading).	Req. Gathering Phase (EX / FG2) [203]	Mini-games contain simple, easy to master mechanics. The system contains no overhead time, with games playable almost immediately.

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Table 5.2 – continued from previous page

Design Req.	Meaning	Source	iFitQuest
8. Short Bursts	The game should be comprised of short bursts of activity, mirroring traditional P.E. classes.	Req. Gathering Phase (EX)	Mini-game approach, with each mini-game lasting short periods of time.
9. Focused Activities	Mini-game activities should be focused towards the PA they aim to facilitate.	Req. Gathering Phase (EX)	As was discussed in the previous two chapters, each mini-game (including the Mystery Games) was designed to focus different intensities of PA, often taking inspiration from well validated P.E. exercises.
10. Flexibility	The game must be flexible to the constraints of a P.E. class and different fitness needs. The system should flexibly support different play styles.	Req. Gathering Phase (EX / FG1)	Suite of mini-games, with sessions comprised of a series of mini-games (can be as many or as few as required on the day). Mini-game difficulties are suited to the level of the player, while different mini-games facilitate different intensities of exercise.
11. Self-Reporting	The game should utilise self-reporting as part of the feedback mechanism.	Req. Gathering Phase (EX)	The game periodically asks the user to self-report their current levels of enjoyment. The players are also trusted to effectively evaluate their exertion level and use this with the Custom Challenge requirement.
12. Micro-Goals	Small scale challenges and tasks, to provide a regular feedback mechanism.	[32] [233]	1. Win a mini-game. 2. Progress through difficulty levels. 3. Set new PBs. 4. Earn maximal points within a mini-game.

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Table 5.2 – continued from previous page

Design Req.	Meaning	Source	iFitQuest
13. Macro-Goal	The game should contain an overall goal.	Req. Gathering Phase (FG1) [233]	Due to the need for an open and flexible environment, the system does not set impose a Macro-Goal. However, it contains support for a number of Macro-Goals including: 1. Winning the class leaderboard. 2. Improving mystery game personal bests. 3. Completing all games on difficulty level 10. 4. Gaining more points each successive week. 5. Making a self-set points target. 6. Beating a peers' score. 7. Playing as many mini-games as possible.
14. Open Environment	The exergame environment is flexible enough to support emergent behaviour. The game should support the player in their choices, but not remove free will.	Prototype Evaluation 1	The players are free to select which mini-games to play, their own difficulty level, and set their own goals and targets (as none are imposed by the system).
15. Variable Environment	Provide variety in order to combat novelty and appeal to a varied demographic.	Prototype Evaluation 2 [7]	The players are provided with 8 different mini-games, with a variety in the game mechanics, difficulty levels, and physical activity facilitated.

5.4 Summary

In the previous chapter, the mini-games which underpin the iFitQuest system were outlined, along with the design process used to develop them. Through the two prototype evaluations, and the prior work in the field, design requirements were established to aid in the development of a system suitable for an adolescent audience and a school-based evaluation. In this chapter, the final system building upon these requirements, was outlined. The additional changes, taking the game from 5 separate mini-games and moving towards a fully functional suite of mini-games, were outlined, along with the overall system architecture.

With the final system developed, the principal evaluations, designed to answer the research questions outlined in Chapter One, could be undertaken. In Chapter Six and Chapter Seven, the two principal evaluations are outlined, with the key results discussed within Chapter Eight.

CHAPTER 6

Evaluation 1: 5-Week High School Evaluation

This chapter outlines the first of two principal evaluations on the iFitQuest exergame. The purpose of this evaluation was to begin answering the research questions posed within Chapter One.

The evaluation was designed as a medium-length school-based physical activity intervention, run within the context of a P.E. class. By allowing for prolonged usage of the system, an accurate and ecologically valid summary of its success at promoting enjoyable and motivating physical activity would be possible. Additionally, by running the study over a prolonged period of time, it would be possible to gather a richer array of data on the different ways people behaved during the exergame experience, building upon some of the provisional findings outlined in the discussion of the second prototype evaluation. Finally, the evaluation was designed to assess the suitability of iFitQuest for a high school P.E. context. The evaluation utilised a mixed methods approach to data gathering and analysis, using both qualitative and quantitative data sources to answer the research questions. In Section 6.1 further details on the evaluation methodology are outlined.

This chapter is organised as follows; first, an overview of the methodology adopted for the two principal evaluations is discussed, justifying the approaches adopted for both this study and the second evaluation presented in Chapter Seven. Following this, the primary research questions are re-visited to recap on the purpose of the evaluation. The evaluation itself is then outlined, along with the key results and subsequent discussion. Note, as the system evaluation was done in two parts (the evaluation outlined in this chapter, and the additional evaluation outlined in Chapter Seven), the primary discussion occurs within Chapter Eight, where both evaluations are discussed together.

6.1 Methodology

This section outlines the methodology adopted for the two principal iFitQuest evaluations. At the highest level, it was decided that a mixed-methods approach would be adopted, utilising both qualitative and quantitative data sources in combination.

6.1.1 Quantitative Vs. Qualitative

Traditionally within the HCI community, quantitative statistical analysis is used as a means to establish whether research questions have been answered, and hypotheses are likely to be true. Inferential statistical tests are commonly performed on quantitative data. However, for the evaluation of iFitQuest, adopting a solely quantitative approach would not be suitable. As Kaptein and Robertson address, many researchers within the HCI community fail to properly consider the size of their samples or correctly interpret the effect sizes they are observing, resulting in a misevaluation of their systems [97].

Due to the logistical constraints of evaluating iFitQuest within a school context, it was not possible to evaluate the system with enough participants such that quantitative statistical tests with sufficiently high powers could be applied [37].

To augment low powered statistical tests, qualitative data analysis was also considered. As is argued within this section, qualitative research approaches allow for detailed data to be captured on the experience of the individual players, while retaining the holistic interpretation of overall events. To this end, while quantitative analysis was adopted where possible, qualitative data was used throughout the process to augment the findings and provide the details capable of answering the research questions posed within Chapter One.

While individual pieces of quantitative and qualitative data could provide insight into how successful iFitQuest was in terms of facilitating physical activity and enjoyment, the most valuable data with regards to the exergame experience comes from *Case Studies*, constructed using a mixed-methods approach.

6.1.2 Case Study Approach

Yin [234] defines a case study as:

1. A case study is an empirical enquiry that:

   (a) Investigates a contemporary phenomenon in depth and within its real life context, especially when
   (b) The boundaries between phenomenon and context are not clearly evident

2. The case study inquiry:
   (a) Copes with technically distinctive situation in which there will be many more variables of interest than data points and as one result
   (b) Relies on multiple sources of evidence, with data needing to converge in a triangulating fashion and as another result
   (c) Benefits from prior development of theoretical propositions to guide data collection and analysis

The merits of such an approach come from the desire to retain holistic characteristics of real-life events and individual behaviours. As the study was designed to investigate emergent behavioural patterns, rather than imposing controlling constraints, as well as using psychological theories for an explanatory analysis, case studies were the logical choice. As Yin describes, case studies should be used when a “how or why” question is being asked about a) a contemporary set of events and b) over which the investigator has little or no control (i.e. not imposing laboratory controls) [234]. As can be seen in Section 6.2, many of the specific research questions of this study focused on the how and why. For example, “how does self-efficacy affect the exergame experience?”.

While an experimental method like a survey may capture data answering “what” and “how many” questions, for example, “How many people increased their opinion of exergames?”, case studies compliment this approach by providing additional avenues of understanding. As Cook and Payne explain, case studies may be “as adjuncts to experiments rather than alternatives to them” [42], due to the way case studies are well suited to answer the “how” or “why” questions that single data sources alone can miss.

For this evaluation, a single participant was considered as a single case, and conclusions were drawn by evaluating across case studies to find consistencies in behaviour, in a multiple-case study design. By looking for overlaps between participants, the risk that observed behaviour was “unique” and not generalizable was mitigated. To this end, data analysis followed a *pattern matching* approach with *cross-case* synthesis used. Data sources from within a case were gathered to form patterns, which were then analysed across cases for greater validity. It can therefore be concluded that the general approach to analysis followed the *inductive* philosophy of inquiry.

6.1.3 A Mixed Methods Approach

By adopting an approach which makes use of both case studies, constructed from, and in complement to, alternative approaches such as questionnaires, interviews, log-file analysis and observational data, the evaluation adopted a *mixed methods* approach.

Johnson and Onwuegbuzie describe this approach as "a class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" [96, p.17]. Yin states, "mixed methods research can permit investigators to address more complicated research questions, to collect complementary data, and to conduct counterpart analyses" [234, p.63]. In Section 6.3.1, the various data collection methods adopted for this evaluation are outlined. These different methods were then used to create both the individual case studies, and the high-level conclusions in order to answer the research questions. For example, when considering the prevalence of a novelty effect within iFitQuest, player opinion from questionnaires and interviews, log-file analysis of exercise intensity, and log file analysis of distance travelled, were all individually analysed and then combined in order to draw the conclusions.

For the two principal iFitQuest evaluations, case studies were embedded within the overall evaluation. That is, each case represents one entry (participant) within a larger mixed method study (the suitability of iFitQuest for school-based exergame interventions). Mixed methods are therefore used to both construct the individual case studies and to combine the case studies with other methods in order to draw the appropriate conclusions.

According to the typology of mixed methods research design of Leech and Onwuegbuzie [111], the process adopted for this evaluation can be classed as a *fully mixed concurrent dominant status design*. This comes from the fact that both qualitative and quantitative data was utilised for the analysis (fully mixed), the quantitative and qualitative data was utilised within the same phases of the study (concurrent), and the dominant status comes from that fact that the qualitative data techniques utilised for the construction of the case studies took precedence over quantitative data, i.e. observation, interview and questionnaire answers were more dominant than the quantitative measurements from the log-files or questionnaire scales.

Throughout this thesis, various approaches to mixed methods data analysis were adopted. When integrating qualitative and quantitative data, a *merging* approach is often adopted. In these cases, quantitative and qualitative data is analysed, and then merged through simultaneous reporting. This is seen throughout the case studies in Section 6.9. Further to this, a *Convergent Parallel Design* is often utilised. The qualitative and quantitative data is collected and analysed in isolation, after which the separate data sources are compared or related in order to allow for accurate interpretation. One example of this is during the discussion on Novelty Effects, with three separate sources analysed before a conclusion is drawn.

6.1.4 Ensuring Validity

When adopting a mixed methods approach to data analysis, it is important that approaches are taken to ensure validity. In order to ensure maximum validity, the following steps were taken during both principal evaluations:

- Research questions were properly defined before analysis took place, see Section 6.2.
- Triangulation of sources was adopted where appropriate. For example, questionnaire data was compared with interviews and log-files to ensure that interpretation was accurate and consistent.
- Triangulation across researchers where possible. Multiple researchers were present for a number of sessions. Data was cross checked across researchers to ensure consistent interpretation.
- Peer examination of data. When a single researcher coded the data, peer examination was adopted to ensure for consistent interpretation.
- Prolonged exposure to the evaluation. To ensure that the qualitative data was most accurate, researchers were exposed to as many evaluation sessions as possible.
- Member checking with participants where appropriate. On occasion, interpretation of data was cross checked with the participants themselves. For example, observation notes and questionnaires answers were often checked during the post-evaluation interview.

A further consideration for ensuring validity is that of sampling. Within both Chapter Six and Chapter Seven, a number of case studies are presented. Case Studies were selected using a mixture of *maximum variation* and *deviant* approaches to data sampling. That is, the case studies were meant to highlight both the variety of behaviour across the participants while also highlighting those participants that had particularly unusual or interesting data. While all participants formed the basis of a case study in Chapter Seven, it is those that represented the edge cases and variations that were chosen for inclusion within text of this thesis.

6.2 Purpose Revisited

This evaluation represented the first time that iFitQuest had been evaluated over a prolonged period of time; in this case, four play sessions spread over 5-weeks. Thus, this evaluation provided greater detail on the high-level success of the game: was it enjoyable to play, and did it facilitate physical activity? Additionally, the prolonged nature provided greater detail on its suitability for a school context. By incorporating the additional dimension of time, this study allowed for the first real insight into novelty effects, and the first detailed look at the participants' in-game behaviour, in particular the way in which self-efficacy influenced the experience.

As a reminder, in Chapter One, the following primary research questions were outlined:

RQ 1. To what extent can a location-aware exergame played within a school-based context promote physical activity, while remaining enjoyable and motivating?

RQ 2. Which features and elements of iFitQuest contributed towards the exergame experience of the participants, and the overall success of the system?

RQ 3. To what extent can self-efficacy be utilised to understand and explain the exergame experience?

With these in mind, the following more specific research questions were adopted for this evaluation, each contributing in part to the overarching questions of this thesis:[1]

6.1 Is iFitQuest enjoyable to play?

6.2 Is iFitQuest physically demanding?

[1]A Research Question Schema can be found in Appendix G, which highlights how each sub-question relates to the three overarching principal research questions.

(a) Can iFitQuest facilitate prolonged PA?

(b) Can iFitQuest facilitate a range of PA intensities?

6.3 Is there a novelty effect within the iFitQuest system?

6.4 What is there to learn about the exergame experience through prolonged play?

(a) Does player behaviour change with time?

(b) How does the self-efficacy of the participant affect their experience?

(c) How does gender affect the participants' experience?

(d) What can be learned about players' in-game motivation?

6.5 How does iFitQuest fit within the school context for a prolonged intervention?

By adopting a user-centred design approach, and evaluating high fidelity prototypes, it was hoped that iFitQuest would successfully meet the requirements of an exergame and seamlessly integrate into the school context. However, due to the exploratory nature of this work, no hypotheses were generated for the above research questions.

6.3 Method

6.3.1 Data Gathering

As was outlined in the introductory section of this chapter, a mixed method approach with the aim of constructing participant case studies was adopted. Throughout the evaluation, the following methods of data collection were used:

1. Pre- and Post-evaluation questionnaires.
2. In-game log-files.
3. Researcher observations.
4. P.E. teacher (expert) observations.
5. Case-study interviews.

These methods are consistent with those outlined by Nacke et al. in their work on evaluating experiences within serious games [146].

All of the participants completed a pre-evaluation questionnaire in order to gather details on their background, including their attitudes towards exercise, their P.E. class, video games and exergames. They were also asked to fill out an exercise self-efficacy questionnaire. Participant backgrounds were used to explain in-game behaviour as well as enable pre- and post-evaluation comparisons.

The post-evaluation questionnaire, as well as containing the background aspects outlined above, also contained a number of open ended questions, asking the participants to evaluate their experience. The questions focused on the general exergame experience, the specific mini-games and the participants' preferences towards these, and which aspects of the games provided the greatest amount of motivation. As well as providing a more detailed picture of the overall experience, the purpose of the post-evaluation questionnaire was to link certain elements of the exergame experience to participant demographics. For example, did participants with high levels of self-efficacy find motivation from a particular element of iFitQuest?

The in-game log-files provided a detailed picture of the individual game sessions. The log-files showed what mini-games the participants were playing, in which order, and at what difficulty, as well as how far they were travelling, at what speed, and their levels of enjoyment and exertion throughout a game. The log-files made it possible to establish whether participants were adopting certain in-game strategies, such as how they selected which game to play, or how they made use of custom difficulty changes. Additionally, they give a detailed insight into the amount of exercise the participants got, by tracking the distance and speed at which they were travelling over the course of a session. Note, the in-game self-reporting of enjoyment and exertion is not included within the analysis of this evaluation. While effective during the second prototype evaluation, participants found it distracting during the prolonged evaluation. During post-evaluation interviews it was established that participants generally chose to ignore the feature or input random values. In Chapter Nine potential solutions to this issue are discussed. Therefore, the self-reported values analysed within this chapter are those established from the pre- and post-evaluation questionnaires.

Taking notes throughout each session, a researcher was present to document details of the session not recorded within the in-game log-files. This included the general attitude and emotion of the participants, and how the participants were interacting with one another.

During each session, the class P.E. teacher was present, giving general observation on the attitude and physical activity levels of the class and how this would compare with behaviour in the traditional P.E. session. This included intensity levels and type of physical activity, as well as the performance of specific individuals relative to what she would expect to see in her class.

Finally, post-evaluation, three one-to-one semi-structured interviews were conducted. The participants were selected on the basis that their questionnaire results and log-files highlighted them as interesting case-studies, due to their unique, unusual or contrasting behaviour whilst playing the game.

6.3.2 Participants

In total 14 participants (one complete P.E. class) were recruited from a local high school. The P.E. class was a non-certificated, core subject class of mixed-ability. The class was recruited on advice from the P.E. department due to the diversity of the participants in terms of gender, ability and attitude. The class were given a trial day after which they voted on whether they wanted to use the game in class rather than their timetabled activity of basketball, meaning that participation was optional. The class unanimously voted in favour of using iFitQuest for the remainder of their P.E. classes.

The class was comprised of 9 females and 5 males. As the class came from a single year group, all participants were aged either 14 or 15 (mean = 14.08, median = 14).

As the participants came from a mixed-ability non-certificated class, it was expected that there would be a variety of attitudes towards exercise, P.E., and their own fitness levels. Despite the P.E. teacher's admission that in general fitness levels were low, the class self-reported themselves with medium to high fitness levels (median and mode = 6.0, mean = 6.85, sd = 1.57, rating between 1 and 10, range = $5-9$). The class also had a generally positive attitude towards exercise (median and mode = 8.0, mean = 7.00, sd = 2.00, rating between 1 and 10, , range = $2-9$) and their P.E. class (median = 8.0, mode = 7.0, mean = 7.15, sd = 2.61, rating between 1 and 10, range $1-10$). While the medians and modes highlight generally positive attitudes, the ranges highlight the mixed nature of the participants.

Table 6.1 outlines the video gaming and exergaming habits of the participants. Please note, only 13 of the 14 participants provide pre-evaluation information for this aspect.

The self-efficacy of the participants was measured pre-evaluation as a potential indicator of in-game experience and behaviour. As with the second prototype evalu-

Table 6.1: Participants' Gaming Background.

Description	Video game Frequency	Exergame Frequency
Never	4	5
Once or twice per week	7	7
Most days	2	1
Everyday	0	0

ation, the Pender Instrument [159] was used for this purpose. The mean self-efficacy score of the participants was 2.71 (sd = 0.5) with the median score 2.75, range = 1.875 – 3.375. Again, the class exhibited medium to high scores. While the range shows the diversity in the class, it also highlights no one had particularly low exercise self-efficacy, with the lowest score in the class 1.875. The full details of 13 participants is outlined in Table 6.2, one participant was absent and did not return their questionnaire before taking part in the evaluation. Their pre-evaluation results were thus discarded for validity.

Table 6.2: Pre-evaluation self-reported scores.

Name[2]	Gender	Fitness	Enjoy Exercise	Enjoy P.E.	Enjoy Exergame	Self-Eff.
Sophie	F	6	6	8	8	2.750
Emily	F	6	5	4	6	3.250
Lucy	F	9	9	8	9	2.625
Isla	F	6	8	9	4	2.875
Jessica	F	9	9	7	8	3.375
Jack	M	8	8	8	7	3.000
Ross	M	8	7	9	9	2.625
Lewis	M	9	8	10	7	3.125
James	M	5	9	9	8	2.000
Daniel	M	6	2	7	7	3.250
Laura	F	7	6	1	1	2.375
Ava	F	5	6	4	6	2.125
Chloe	F	5	8	9	8	1.875

[2]Pseudonyms used for anonymity.

6.3.3 School Profile

The school selected for the evaluation was a state-run secondary education school. Secondary schools in Scotland support the education of children from the ages of 11-12 (age at the start of first year) to 16-17 (age at the start of sixth year). The school selected contained a diverse population, with the catchment area encompassing both affluent areas, and those with a lower socio-economic status.

The school selected was identified in the most recent government inspection report as 'good' in terms of the environment, level of teaching and attainment of the pupils. The teachers supporting the evaluation were well trained and commended for their well prepared and organised lessons. The children who played iFitQuest generally had good English, and mathematical skills, meaning that understanding and answering the questionnaire was well within their cognitive capabilities [59].

The P.E. department had good facilities, including one regulation size grass rugby field that was used for the evaluation.

6.3.4 Procedure

Before undertaking the evaluation, full ethical approval was granted by the Heriot-Watt University Computer Science ethics process. The participating class were given a trial session in order to experience the game before opting into the evaluation. The class unanimously voted to use iFitQuest within their P.E. class, although participants' were reminded that they could drop out of the evaluation at any stage. Consent was also sought from each participant individually, as well as their parent / guardian, through a signed consent form (See Appendix A).

The evaluation consisted of 4 sessions spread over the course of 5-weeks. The initial plan was to evaluate the game once per week, but due to adverse weather and the constraints of the school timetable, one session had to be cancelled and could not be rescheduled.

The study consisted of four separate 55 minute sessions (the maximum amount of time afforded by the school timetable), although as was outlined in Chapter Four, this does not equate to 55 minutes of physical activity time. At the end of the four sessions, a separate 1 hour session was used to complete the post-evaluation questionnaire, and for the three one-to-one interviews to be conducted.

The length of the study was dictated by the school calendar, with the study concluding at the point where the participants progressed to the next year of study and thus selected different subjects. The study was of sufficient length such that the players could properly experience and evaluate the game, and there was sufficient time such that changes in behaviour and attitude could potentially be observed. The 5-weeks represented a similar length of study to that seen in other prolonged exergame evaluations such as the American Horsepower Challenge (4- to 5-week blocks) [229, 230] and Fish‘n’Steps (6-weeks) [115] as well as Sun’s 4-week intervention [204], although it is noted that in these studies the systems were more frequently used than once per week. The 5-week evaluation was also of sufficient length to facilitate behavioural changes and properly assess physical activity, as highlighted by the literature review outlined in Chapter Two [189].

As the pupils had already trialled the system, and were therefore familiar with the gameplay and concepts before the first session, the procedure for each session was as follows:

- Initial briefing by researcher.
- Non game warm-up with the class P.E. teacher.
- Free time to play game.
- Short de-brief and discussion.

As the class had 14 registered pupils, and only 10 iPhone devices were available, on occasion participants had to share devices. When there were more participants than devices, the children continued to play individually (i.e. one child to each device), but half way through the session a child would log-off the system and a new participant would log-on. Despite the potential problems this could cause, due to absences, there were never more than 12 participants in class at the one time, and thus only 2 devices had to be shared during any single session.

6.4 Results

6.4.1 Overview

Over the course of the five week evaluation, participants had the opportunity to play the game on 4 occasions. In total, the game was played 45 times by the 14 participants. On average, each participant played the game between 3 or 4 times (mean = 3.21,

Table 6.3: Distance covered by each participant, rounded to the nearest metre.

Participant	Session 1	Session 2	Session 3	Session 4	Total
Sophie	150	131	678	n/a	959
Emily	14	234	1157	1102	2507
Lucy	1228	475	1231	1475	4409
Isla	1058	1309	1322	2800	6489
Jessica	1677	1556	n/a	906	4139
Jack	917	2106	1632	2843	7498
Ross	1448	1006	1328	2257	6039
Lewis	926	1074	1559	3214	6773
James	1424	921	1152	1834	5331
Daniel	n/a	799	920	1810	3529
Laura	n/a	n/a	839	n/a	839
Ava	152	n/a	n/a	1577	1729
Chloe	133	393	n/a	635	1161
Sarah	554	n/a	n/a	41	595
Totals	**9681**	**10004**	**11818**	**20494**	**51997**

mode = 4), with school absences and injury accounting for the missed sessions. Seven participants played the game the maximum number of times, four missed one session, two missed two sessions, and one missed three sessions.

In total, the participants played the game for 746 minutes and 16 seconds (12.44 hours). This equates to approximately 53 minutes per person, with an average gaming session lasting 16 minutes 35 seconds. While these figures may appear low, 15 to 20 minutes is what was expected due to the timetabling constraints of a P.E. class (outlined in Chapter Four), and consistent with the findings of Sallis et al. [179] who found that on average children achieve only 17.8 minutes of physical activity within their P.E. class. When accounting for pre- and post-session changing time and the short researcher de-briefs, the pre-game warm-up and the fact that on occasion participants had to share devices, the average session length represents a large proportion of the available time.

Over the course of the evaluation, the participants covered a total distance of 51995.0 metres (32.3 miles or 52.0 kilometres). This equates to roughly 1155 metres per session, or 3714 metres per person over the course of the study. A range in total distances of 594.95m − 7496.91m was observed. The total distances for each of the

14 participants, broken down by session, is outlined in Table 6.3.

Over the course of the four sessions, a total of 553 mini-games were played. In Table 6.4, the breakdown of plays per mini-game is shown. While certain games were played more frequently than others, all games received some play. This is discussed in greater detail in Section 6.4.2.

Table 6.4: Overall number of plays for each mini-game across the evaluation.

Mini-Game	Plays	%
Escape the Wolf	136	24.6%
Collect the Coins	185	33.5 %
Follow the Chicken	48	8.7%
Return the Sheep	35	6.3%
Visit the Fields	30	5.4%
Mystery Games	119	21.5 %

6.4.2 General Experience

Overall, the class found the game 'moderately to highly' enjoyable, with the median and mode self-reported enjoyment score 6.0 on a scale between 1 and 10 (range = 5 – 8, mean = 6.3, sd =1.14). Jessica stated, "it was a good game and I enjoyed taking part", while Isla emphasised her enjoyment of the physical activity aspect of the game, "because I like running; I think this is a good game for me". Similarly, Ross stated that the games were "fun to play and they keep you fit", while Lewis enjoyed the social aspect of the game saying that it was "enjoyable with friends". In contrast to the previous prototype evaluations, there was no statistically significant difference detected in terms of enjoyment by gender (U = 12.0, Z = -1.457, p = 0.158).

When asked whether they would like to play the game again, 10 of the 14 participants (71.4%) said they would. Of the reasons given by those who didn't want to play the game again, 2 of the 4 stated that they liked the game, but they wouldn't want to play it as regularly (i.e. within their P.E. class), one stated that they enjoyed the game but had begun to get bored, and one stated that they simply did not like anything that required them to run. In general, it can be concluded that the game was successful with regards to facilitating enjoyment.

Looking deeper than general enjoyment, participants were asked to provide additional details on the specific mini-games. Participants were asked to rank the 6 mini-games (the three mystery games were classed as a single game due to the fact they were combined on the game interface) from their favourite to their least favourite. Table 6.5 provides the rankings given to each game from the 14 participants.

Table 6.5: Participants' mini-game rankings.

	Participant Number													
Mini-Game	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Escape the Wolf	1	3	6	4	3	5	4	1	2	4	1	4	4	4
Collect the Coins	3	2	1	1	1	2	2	2	3	6	2	1	1	1
Follow the Chicken	4	4	5	6	5	3	6	6	4	5	3	4	5	6
Return the Sheep	5	6	2	5	4	6	5	5	5	1	4	4	6	3
Visit the Fields	5	5	3	3	6	4	3	4	6	2	5	3	3	2
Mystery Games	1	1	4	2	2	1	1	3	1	3	6	2	2	5

A number 1 by a game means that this was the participant's favourite game. In the event of a tie, participants could rank two games equally. Table 6.6 provides the overall points awarded to each game based on a reverse coding scheme where by the number 1 ranked game received 6 points, decrementing to the lowest rank game which received 1 point.

Table 6.6: Overall mini-game points based on individual participant rankings.

Game	**Points**
Escape the Wolf	52
Collect the Coins	70
Follow the Chicken	32
Return the Sheep	37
Visit the Fields	44
Mystery Games	64

As can be seen from Table 6.6, Escape the Wolf, Collect the Coins and the Mystery Games were the most popular amongst participants. While Follow the Chicken and Return the Sheep scored significantly lower in overall points, Table 6.5 highlights the diversity in interests, with even the generally popular games not appealing to everyone, and the less popular mini-games enjoyed by some. This data is generally consistent with Table 6.4, showing that the most played were also the most enjoyed. An interesting observation by contrasting the two tables is that the Visit the Fields game was the least played of all mini-games, yet the 4$^{\text{th}}$ most popular game. Likewise, Follow the Chicken was the 4th most played, yet least popular. This provided the first insight into the fact that when selecting which mini-game to play, participants did not simply select those they enjoyed playing most. This data also serves as evidence for the merits of a suite of games, with all games played on a number of occasions, and a diversity in preferences despite a relatively small sample size.

Table 6.7 shows the reasons given by participants when outlining why the prefered their favourite game. In Table 6.8, the reasons for disliking their least favourite games are outlined.

Table 6.7: Participants' reasons for liking a specific mini-game.

Reason	Freq.
It was the simplest / easiest to play	4
It was the most fun	2
It was the most challenging	2
You had to try and beat your previous scores	2
I liked the theme of the game	2
It had the most to do in it	1
It had clear goals	1
I didn't need to be distracted by the game screen	1
It was the least challenging	1

Table 6.8: Participants' reasons for disliking a game.

Reason	Freq.
It was too hard	4
It was boring	2
There was a bug / problem with the game	2
It was too simple	1
There was not enough to do	1
I disliked the games themes	1
I felt the game didn't have clear goals	1

As can be seen from Table 6.7, participants appreciated simple and easy to understand mini-games. Among other factors, participants enjoyed mini-games that were "fun", "challenging", had good themes and utilised the concept of personal bests. In support of the simple game mechanics, Table 6.8 shows that the most commonly identified reason for disliking a mini-game was that "it was too hard". The importance of fun and goals was confirmed, participants providing “it was boring” and “too simple”, “not enough to do” and a lack of “clear goals” as additional reasons for disliking a game.

6.5 Physical Activity

The results in the previous section highlight the ability of iFitQuest to facilitate enjoyment. However, in order to be fundamentally successful, an exergame must encourage and facilitate physical activity.

The participants felt that they got a moderate to high workout whilst playing the game, reporting their overall exertion level while playing the game with a median and mode of 6.0 and a mean of 6.4 on a scale of 1 to 10 (range $= 4 - 9$, sd $= 1.39$).

Additionally, it is possible to look at the proportion of time each participant spent exercising at a MVPA intensity. This was calculated by analysing the log-file data. The logs showed each mini-game played by a participant during each session, and the average speed (in mph) at which they played those mini-games. Using this, the physical activity intensity for each mini-game was calculated using the same method outlined in Chapter Four, on the guidance of the Centre for Disease Control and the American College of Sports Medicine.[3] Table 6.9 shows the percentage of mini-games that each participant spent playing at a MVPA intensity. I.e. a 100 means that the corresponding participant played 100% of their mini-games at a MVPA level, while a 0 means that all mini-games were at a lighter intensity than MVPA (not that zero games were played). Note, a shaded cell represents a session missed by the participant.

As can be seen from Table 6.9, all 14 participants experienced at least some MVPA whilst playing the game. This highlights the ability of iFitQuest to not only facilitate physical activity, but physical activity at an intensity which contributes towards daily physical activity guidelines. While some participants played a high proportion of mini-games at a MVPA intensity, e.g. Jack, some very rarely reached the MVPA threshold, e.g. Chloe. This highlights the flexible nature of iFitQuest, with the ability to support different levels of physical activity. For the more active participants in the class, such as Jack and Isla, the game supported their higher fitness levels. However, for those generally less enthusiastic about physical activity, such as Chloe and Sophie, the game

[3]The CDC heuristic allows for conversion between speed in mph and physical activity intensity. Using this heuristic and the average speed calculated within the log-files, it is possible to calculate what proportion of mini-games were played at a MVPA level.

Table 6.9: Percentage of mini-games played at a MVPA level for each participant, split by session.

	Session Number			
Name	**1**	**2**	**3**	**4**
Sophie	50	0	16.7	
Emily	0	0	42.9	0
Lucy	33.3	100	70	81.8
Isla	62.5	85.7	88.9	57.1
Jessica	100	75		75
Jack	100	72.7	78.6	100
Ross	60	53.8	75	89.5
Lewis	41.2	69.2	87.5	57.1
James	72.7	60	50	57.1
Daniel		36.4	33.3	40
Laura			66.6	
Ava	75			25
Chloe	0	0		12.5
Sarah	28.6		0	

allowed them to still participate, but supported a less physically intense experience.

Looking at the breakdown of physical activity intensity by mini-game (Table 6.10) again highlights the diversity and flexibility of the iFitQuest system. While all mini-games allow participants to participate at a range of intensities, Table 6.10 highlights that some mini-games are more suited to supporting specific intensities than others. It is positive to note that the addition of the Mystery Games was an effective way to facilitate more intense physical activity. No single mini-game stands out as consistently supporting moderate intensity exercise, which could be viewed as a shortcoming in the system. This is discussed in Chapter Eight, with suggested improvements to address this issue outlined in Chapter Nine.

As a final point, the expert P.E. teacher who observed every session was on the whole positive about the experience. She stated that the general level of exercise was as she would expect from her 'standard' P.E. classes, and that she was impressed with the enthusiasm of the students for the game. She did however state that in her opinion, the game had not necessarily reached out to those who usually had low P.E. participation and motivation. That is, the children that embraced iFitQuest were

Table 6.10: Physical activity intensity by mini-game.

Game	Avg. Speed (mph)	Light	Mod.	Vig.
Escape the Wolf	6.67 (vig.)	31.4 %	7.0 %	61.6 %
Collect the Coins	3.02 (mod.)	59.3 %	25.2 %	15.5 %
Follow the Chicken	4.32 (mod.)	34.8 %	28.3 %	36.9 %
Return the Sheep	2.13 (light)	74.3 %	20.0 %	5.7 %
Visit the Fields	2.80 (light)	76.7 %	13.3 %	10.0 %
Mystery Games	6.51 (vig.)	14.8 %	10.9 %	75.3 %

those that generally embraced traditional P.E. lessons. One hope for exergames is that they can appeal to new demographics, and provide a means to exercise for those put-off by traditional P.E. lessons. In the opinion of the P.E. teacher, iFitQuest has failed in this respect.

To summarise, through an analysis of log-file data it is possible to conclude that iFitQuest is capable of facilitating physical activity of various different intensities. Each of the mini-games support a range of physical activity intensities, allowing participants of all backgrounds to experience each of the games. Importantly, the log-file analysis confirms that iFitQuest can help players in achieving their daily physical activity guidelines while also avoiding sedentary behaviours.

6.6 Motivation

Participants rated their motivation to perform physical activity whilst playing iFitQuest as moderately high, with a median score 6.5, the mode as 8.0, and the mean as 6.57 (sd = 2.06) on a scale of 1 to 10. As these scores came from the post-evaluation questionnaire, at which point one may expect to see a novelty effect (discussed in Section 6.7), it represents a positive outcome for iFitQuest that the scores were still moderately high. When discussing their level of motivation, Jessica stated, "although I was often tired, once I got into the game, I felt more motivated", while Daniel liked "that there were different levels". Conversely, two participants found the game "repetitive", which resulted in them feeling less motivated.

As well as an overall motivation score, participants were asked to quantitatively rate from a provided list the aspects of the evaluation which provided them with the greatest source of motivation. The following aspects were rated highest by the participants; note, participants could rate a number of aspects as equally motivating.

Table 6.11: Most motivating aspects of iFitQuest.

Aspect	Freq.
Trying to improve fitness	6
Trying to earn more points than the rest of the class	4
Trying in order to beat a friend's score	4
Trying to win at the mini-games	4
Trying through enjoyment of the mini-games	3
Trying to improve mini-game scores	3
Trying to earn maximum points	2
Trying to get praise from the teacher	2
Trying to beat self-set points goals	1

Table 6.11 highlights the disparate nature of motivational factors provided by iFitQuest. Additionally, within the confines of a single exergame, it highlights that the design requirements of flexibility and different micro- and macro-goals have been met. By allowing for this flexible environment, it allows participants to harbour motivation from the elements important to them, without discriminating against those who may have specific interests.

6.7 Novelty Effect

Discussed in Chapter Three, the notion of novelty effects within exergames is well established and of potential concern to practitioners working in the field. It was therefore important to investigate whether such an effect could be observed within a 5-week evaluation of iFitQuest. Within the literature, those practitioners that have discussed the notion of a novelty effect usually consider changes in step counts with time, as most longitudinal evaluations within the domain have been based on pedometer trials [115, 163]. An analogous approach for this evaluation was to consider the distance travelled by each participant, and investigate how this changes with time. However, emphasised within Chapter Two, and subsequently considered during the design of iFitQuest, is the importance of exercise intensity. Considering only the distance players travelled could prove misleading. For example, someone may travel a shorter overall distance, but spend a greater portion of their time exercising at a vigorous intensity. The shorter distance does not mean a novelty effect is present and the player is less motivated to play the game. Therefore, a mixed-methods approach to evaluation was utilised. In order to answer the question of whether a novelty effect was present, the opinions of the participants (similar to the novelty analysis of Sun et al. [204]), and a breakdown of exercise intensity by session were also considered in addition to the distance travelled by the players.

6.7.1 Exercise Intensity

One aspect for consideration was the average physical activity intensity at which participants played the mini-games. Log-file analysis was used to establish for each participant the percentage of mini-games they played at either a moderate of vigorous intensity across the duration of the evaluation. If over the four sessions, someone showed a steady decline in percentage of MVPA mini-games, this could be one possible indication of a novelty effect.

In Figure 6.1 the percentage of mini-games played at a moderate or vigorous intensity are graphed by participant and across the four sessions. As not all participants were present throughout the study, some of the lines cover only 2 or 3 sessions. As one participant was only present for a single session, Figure 6.1 only includes the remaining 13 participants. The percentages were calculated by using the average mini-game speed measurements from the in-game log-files, and the technique outlined previously in Section 6.5. The bold black line indicates the average MVPA percentage for each session.

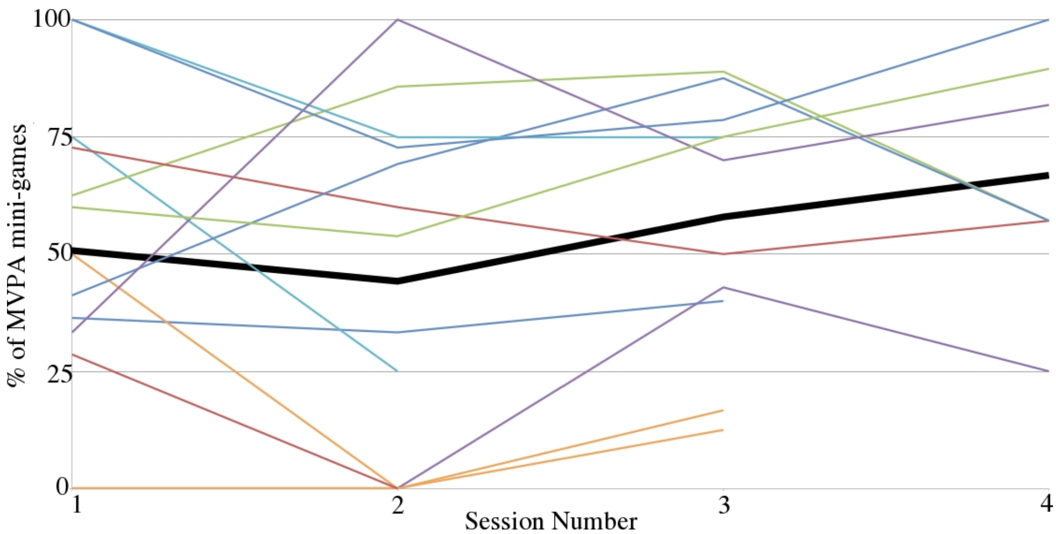

Figure 6.1: Graph showing how the participants' MVPA % changed by session.

As can be seen from the average line, there is a general increase in percentage of MVPA across the four sessions. Although session two is slightly lower than session one, there is a subsequent increase in session three and session four. Table 6.12 highlights how the percentage of MVPA mini-games changed for the individual participants, i.e. what frequency of participants increased, decreased or maintained their MVPA percentage between sessions one and session two, etc.

Table 6.12: Participants' mini-game MVPA changes between sessions.

	Session 1 & 2	**Session 2 & 3**	**Session 3 & 4**
Increase	3	8	4
Same	2	1	0
Decrease	8	2	3

Table 6.12 reiterates what was seen in Figure 6.1. While there was a general decrease in mini-game MVPA between sessions one and two, in general people were playing more mini-games at an MVPA intensity in subsequent sessions. This is in contrast to what one would expect if a novelty effect was present, in which case participants would have lower motivation to play the game and as such would exercise at lower intensities.

It is acknowledged that this method alone does not provide a complete picture of whether a novelty effect was present. As was highlighted in Section 6.5, and within the second prototype evaluation in Chapter Five, each mini-game generally facilitates different intensities of physical activity. Thus, any increase or decrease in MVPA may actually be due to changes in game selection habits, rather than a change in motivation. Figure 6.1 shows that in general, there was actually a slight increase in MVPA as the evaluation progressed. Even in accounting for the limitations of this method, it does not appear to highlight a novelty effect was present.

6.7.2 Distance

Analogous to the approach adopted for other prolonged exergame evaluations, the distance participants covered by session can be compared to assess whether a novelty effect was present. By looking at how far someone travels in each session, and comparing this with each subsequent session, if someone shows a decline in distance travelled, a novelty effect could be one possible factor influencing their behaviour. As with the analysis of Section 6.7.1, as one participant in the study only completed a single session, they were excluded from the analysis.

Looking at the contrast between each participant's first and last session, 11 of the

13 participants travelled further in their last session played than their first. Table 6.13 shows how the distance covered by each participant changed from session to session.

Table 6.13: Number of participants' increasing or decreasing their distance by session.

	Session 1 & 2	**Session 2 & 3**	**Session 3 & 4**
Increase	7	9	6
Decrease	6	2	1

As can be seen, between each pair of sessions, the majority of people were increasing the distance they were travelling, with the proportion of those increasing the distance notably higher between sessions 2 & 3, and sessions 3 & 4. This data is once again in contrast to what would be expected were a novelty effect present.

Running a repeated measures ANOVA on the distances travelled by those participants that were present for each session (7 participants), with Mauchly's test indicating the sphericity should be assumed ($x^2(5) = 3.687$, $p = 0.753$), highlights that the distances covered per week are statistically significantly different ($F(3,18) = 12.660$, $p < 0.0005$, $r = 0.678$).

By looking at the pairwise comparisons (Bonferroni post-hoc tests) between the different weeks, the following information is obtained:

1. There was no significant difference between session 1 and 2, and session 1 and 3.

2. There was a statistically significant difference between session 1 and 4, with the distance covered in session 4 greater than that in session 1.

3. There was no significant difference between session 2 and 3.

4. There was a significant difference between session 2 and session 4, with the distance covered in session 4 greater than that in session 2.

5. There was no significant difference between session 3 and any other session.

The tests revealed a significant difference in distance covered between session 1 and 4 ($CI_{.95}$ = -2362.193 (lower) -68.839 (upper), $p < 0.05$) and session 2 and 4 ($CI_{.95}$ = -1909.203 (lower) -490.305 (upper), $p < 0.05$). The between weeks analysis is highlighted in Table 6.14.

Table 6.14: Pairwise comparisons of the distance travelled each week.

Session	1	2	3	4
1		n.s.	n.s.	$p<0.05$
2	n.s.		n.s.	$p<0.005$
3	n.s.	n.s.		n.s.
4	$p<0.05$	$p<0.005$	n.s.	

While the sample size is small, and thus conclusions on the significance tests must remain tentative, this statistical analysis is consistent with the frequency data in Table 6.13. Not only were distances not decreasing with time, there was a statistical increase in distance travelled in session 4, relative to sessions 1 and sessions 2.

6.7.3 Player Opinion

Another consideration was the opinion of the participants themselves, similar to the approach adopted by Sun et al. in their novelty effect analysis [204]. As was highlighted in Section 6.4.2, 71.4% of participants stated that they wanted to play the game again. Of the four participants that said they would not like to play the game again, three provided qualitative data hinting at a novelty effect. Two stated that they continued to enjoy the game, but they did not want to play it as part of their P.E. class anymore, while one stated that they were bored with the game. However, the remaining 10 participants were happy to continue playing the game as part of their class. One participant stated in the post-evaluation interview that they "could have played it for a few more weeks" before becoming bored with the game.

While for some participants the novelty of the game had possibly begun to wear off, the majority of the participants wanted to keep playing the game as part of their P.E. class. In this regard, a novelty effect was not observed for the majority of participants.

6.7.4 Summary

To summarise, no single measure considered alone provides sufficient insight into whether iFitQuest suffered from a novelty effect within this evaluation. Player opinion does not always reflect reality, distances travelled do not account for exercise intensity, and intensity by session does not account for changes in mini-game play habits. However, when all three aspects are considered together, it provides a more valid and accurate overview regarding the potential novelty of iFitQuest. Considering the findings of the three separate analyses, it appears that no novelty effect was observed during the four sessions of play. Although some participants did not wish to continue evaluating the system, the analysis of exercise intensity and distance covered highlight that participants on the whole remained motivated and physically active throughout the evaluation.

6.8 Participant Changes

The research questions outlined at the beginning of this chapter focus on establishing the success of iFitQuest as an exergame and better understanding the exergame experience. One measure of the success of iFitQuest is the way it affected those players that participated in the evaluation. Table 6.15 shows the pre- and post-evaluation scores for the 13 participants involved with the study (as was discussed in Section 6.3.2, one participant did not complete a pre-evaluation questionnaire).

Name	**Self-Reported Fitness**		**Enjoy Exercise**		**Enjoy P.E.**		**Enjoy Exergame**		**Self-Eff.**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Sophie	6	7	6	6	8	6	8	4	2.750	2.250
Emily	6	4	5	4	4	1	6	6	3.250	3.000
Lucy	9	8.5	9	9	8	8	9	8	2.625	3.125
Isla	6	7	8	8	9	8	4	3	2.875	3.500
Jessica	9	8	9	9	7	5	8	5	3.375	3.625
Jack	8	8	8	9	8	9	7	9	3.000	3.000
Ross	8	7	7	7	9	8	9	8	2.625	3.000
Lewis	9	9	8	10	10	10	7	7	3.125	2.750
James	5	6	9	8	9	8	8	7	3.000	2.750
Daniel	6	2	2	0	7	7	7	7	3.250	2.250
Laura	7	3	6	5	1	0	1	0	2.375	1.875
Ava	5	7	6	7	4	5	6	5	2.125	2.125
Chloe	5	6	8	5	9	4	8	8	1.875	1.625

Table 6.15: Pre- and post-evaluation scores for each participant.

By conducting Wilcoxon Signed-Rank tests (2-tailed) for the pre- and post-evaluation questionnaire categories, and a paired samples t-test (2-tailed) for the pre- and post-evaluation self-efficacy scores, the following was observed:

1. There was no significant difference between pre- and post-evaluation scores for self-reported fitness, Z = -0.627, p = 0.582.

2. There was no significant difference between pre- and post-evaluation scores for enjoyment of exercise, Z = -0.791, p = 0.539.

3. There was a significant difference between pre- and post-evaluation scores for enjoyment of P.E., Z = -2.140, $p < 0.05$. The effect size is large ($r = 0.59$). Post-evaluation, the participants' enjoyment of P.E. had decreased.

4. There was no significant difference between pre- and post-evaluation scores for enjoyment of exergames, Z= -1.895, p = 0.09.

5. There was no significant difference between pre- and post-evaluation scores for self-efficacy, $t(12) = 0.832$, p = 0.422.

As was discussed in the introduction of this chapter, these statistical tests are low powered, due to the small sample size. Thus, to get a more in-depth understanding of the data, the frequency data is investigated.

In terms of self-reported fitness, there was a fairly even split between those that felt they had improved their fitness (5), and those that felt they had lowered their fitness (6). While the hope of an exergame should naturally be to improve the fitness of the participants, it is not surprising that some iFitQuest players also lowered their score. Four of those that lowered their score did so by only a small margin, 1 or 1.5 points on a 10 point scale. Of those with a more significant decrease, Laura was the child who only played the game once, and admitted she "hated running", and Daniel (who is discussed in depth in Section 6.9.3) was the least fit male in the class, who regularly compared his performance to his peers, which may have resulted in a realisation that his fitness was lower than expected. As the questionnaires asked participants to quantify their fitness level, rather than directly asking "do you feel fitter having played iFitQuest?", slight changes may be attributable to natural variance.

For enjoyment of physical activity and exercise, 3 participants increased their score, 5 decreased, and 5 reported the same pre- and post-evaluation scores. The most significant jump was Lewis, who increased his score by 2. The largest decrease was from Chloe, who dropped her score from 8 to 5. This is interesting given that she enjoyed the evaluation (rating it 8 out of 10), showing that simply enjoying the game over a short period is not necessarily enough to raise enjoyment of exercise.

As was to be expected based on the above statistical tests, many of the participants decreased their rating of P.E. enjoyment post-evaluation (8 of the participants). While most of the changes represented only small decreases (6 of the 8 lowered their score by only 1 or 2 points on the scale), two of the participants scored their P.E. enjoyment considerably lower. Chloe lowered her score from 9 to 4, while Emily lowered her score from 4 to 1. As was discussed above, it is difficult to explain this behaviour from Chloe, given that she enjoyed the intervention. However, as one may expect enjoyment of physical activity and enjoyment of P.E. to be positively correlated, it is not necessarily surprising that she also decreased her opinion of P.E. despite enjoying the game. As for Emily, it is also difficult to explain her behaviour, given that she enjoyed the evaluation and wanted to play the game again. One potential factor is that in the post-evaluation questionnaire, Emily stated that while she enjoyed the game, she did not like being outside in the cold and having to run on wet grass. She stated she would prefer to play the game indoors. Although this may only contribute in part to the lowered score, it does highlight that location-aware exergame interventions must naturally also compete with the context of the intervention, and enjoyment of the game can not be guaranteed through good game design.

It is disappointing to note that 8 of the 13 participants lowered their score with respect to enjoyment of exergames post-evaluation. As expected, 3 of the 8 participants who lowered their score were also 3 of the 4 who stated they would not like to play the game again (although as discussed in Section 6.4.2, this does not necessarily mean they did not enjoy playing iFitQuest). Additionally, 6 of the 8 participants stated that they regularly played exergames outwith the evaluation of iFitQuest, meaning that their decrease in attitude could be attributed to external factors, especially as many stated they enjoyed the iFitQuest evaluation. While it was the hope that iFitQuest would raise opinion towards exergames, it is not possible to show that any change to opinion can be directly attributed to the game.

Finally, looking at self-efficacy, 4 participants increased their score, 7 decreased their score, and 2 showed no change. Based on variations seen in similar applications of the health promotion model, a change of 0.5 was selected as representing a threshold meriting discussion [73, 220]. Based on this, 5 participants experienced such a change, with 2 increasing their self-efficacy and 3 decreasing. In Chapter Two, Bandura's work on how self-efficacy is established was discussed. He writes, a person's self-efficacy for a task is based upon 1) past performances on said task; 2) vicarious information; 3) persuasive information (such as social influence); and 4) arousal information based upon physiological cues [12]. Based on this, and an analysis of the participants' in-game experience, it is not surprising that Isla and Lucy showed an increase in self-efficacy. Isla (discussed in depth within Section 6.9.2) was heavily motivated by achieving mini-game improvements, at which she was generally successful. Her past performances were therefore positive, one factor that could increase self-efficacy. Additionally, as her peer group had similar motives, the vicarious and persuasive information she received could also have added to her self-efficacy. This is also true for Lucy, who was close friends with Isla, and displayed the same motivations. Conversely, Daniel showed a fairly considerable decrease in self-efficacy. As is discussed in Section 6.9.3, Daniel was partially motivated by points and competition. Relative to his peers, he experienced little success. This would impact his own opinion of his past performance, and given he will have seen his social group succeeding relative to his own performance, vicarious and persuasive information may also have added to a decrease in self-efficacy. The other two participants to show a considerable decrease in self-efficacy, Laura and Sophie, were two of the participants in the class that had the least interest and motivation towards the evaluation. This therefore influenced their performance and effort relative to the class, meaning that a subsequent decrease was to be expected. In summary, while the aim of an exergame should be to increase the players' self-efficacy, given the in-game behaviour of some iFitQuest players, it is not unexpected that some of those involved with the evaluation had lower post-evaluation self-efficacies. The data, although tentative, is consistent with Bandura's theory.

6.9 Case Studies

Discussed in the introduction of this chapter was the importance of getting a deeper understanding of the in-game behaviour of the participants. Although the preceding analysis allows for some high-level conclusions on the success of iFitQuest, it was important to closely examine the participants to better understand the results. Justified in the methodology section of this chapter, a mixed-method approach was adopted to create case studies, highlighting the behaviour and experience of specific participants, augmenting the holistic data already presented.

In this section, three case studies are presented representing three disparate participants in terms of in-game behaviour and background. To be eligible for inclusion in the case study analysis, participants had to be present for at least 3 sessions (to allow for an understanding of behaviour over time) and present during the final session in order to be interviewed. These three cases represented diversity in terms of gaming and exercise background, as well as a range of in-game motivations and game selection habits. The three cases provide both interesting contrast, and interesting overlap, while discussing a wide variety of behaviour and experience.

Note, for each case study, participant ratings are on a scale between 1 and 10 (unless otherwise stated) where 1 is low and 10 is high. As a reminder, the primary discussion of the case studies occurs within Chapter Eight, particularly with respect to the influence of self-efficacy on the participants' behaviour. Thus, while the reader is drawn towards certain key points, they are not discussed at length within this chapter.

6.9.1 Case Study 1: Jack

The first case study focuses on Jack, a 14 year old male with high pre-evaluation exercise self-efficacy (3.0 on the PASS scale of 1.0 to 4.0) and a good attitude towards exercise. Jack rated both his enjoyment of exercise, and enjoyment of his P.E. class, at 9, and his own fitness as 8. The class P.E. teacher confirmed that Jack was towards the higher end of the fitness spectrum, also stating that he was a talented basketball player, who participated regularly in extra-curricular sporting activities.

Jack could be classed as a casual gamer, stating that he only played video games once or twice per week, and that while he had previously tried playing exercise games, he did not own, nor play them on a regular basis. Despite this, pre-evaluation he stated that he quite enjoyed playing exergames, quantifying his enjoyment of them as 7.

Jack provided an interesting example for a case study due to his enthusiasm for the game. Jack was highly competitive during the iFitQuest evaluation, always trying his hardest to earn maximum points (both within mini-games and the overall evaluation), beat his friends' scores, and beat his own personal bests within the mini-games. In order to achieve this, Jack constantly re-evaluated his mini-game selection habits, and even on occasion, tried to cheat the game. Jack is an example of someone who came into the evaluation with a good background in sport, who passionately embraced the system. For Jack, the support for competition between peers provided the greatest source of motivation.

6.9.1.1 Evaluation Overview

As stated in the overview, Jack had a positive evaluation experience. Jack remained throughout the 4 sessions one of the more enthusiastic members of the class, showing a high desire to play the game, and a consistently high motivation to perform well. This is reflected in Jack's post-evaluation enjoyment rating of 8 and in the admission that he would like to play the game again within his P.E. class.

Table 6.16: Jack's pre- and post-evaluation scores.[4]

	Pre	**Post**
Self-reported fitness	8	8
Enjoyment of exercise	8	9
Enjoyment of P.E.	8	9
Self-efficacy	3.0	3.0
Enjoyment of exergames	7	9

Observations of Jack playing the game showed that he was willing to play a mixture of mini-games, with the key factor in his decision process how many points he could earn. Jack was regularly observed comparing scores with his peers, behaviour which he confirmed in the post-evaluation interview.

Table 6.16 shows the pre- and post-evaluation scores for Jack. As can be seen, Jack's enjoyment of exercise, and P.E. slightly increased post-evaluation. Jack also has a higher opinion of exergames post-evaluation, which clarifies the observations that Jack enjoyed the exergame intervention. There was no change to Jack's self-efficacy during the study, but as he was already at the higher end of the spectrum, it can be considered positive that his high self-efficacy was maintained.

6.9.1.2 Gameplay Patterns

As can be seen from Table 6.17, Jack generally focused on the Collect the Coins game. Jack also regularly played the Mystery Games, and as such, it was important to clarify whether this was simply to unlock the Collect the Coins game again, or due to a desire to play the Mystery Games themselves. In the post-evaluation questionnaire Jack ranked the Mystery Game as his favourite game, stating "I enjoyed the mystery game the best as...you are able to beat your high score", highlighting his motivation

[4]Note: For all participants, pre- and post-evaluation scores were measured on a scale between 1 and 10, excluding self-efficacy which was measured between 1.0 and 4.0.

Table 6.17: Jack's session by session game selection habits.

	Session Number			
Mini-Game	**1**	**2**	**3**	**4**
Escape the Wolf	0	3	3	1
Collect the Coins	10	3	5	13
Follow the Chicken	0	0	0	0
Return the Sheep	0	1	1	0
Visit the Fields	0	0	2	0
Mystery Games	3	5	5	4

to improve upon his personal bests.

Jack stated in his post-evaluation questionnaire that he, "chose the games that gave me the most points". When asked in the interview whether success, or the amount of physical activity required in a mini-game influenced his decisions, Jack stated that success was important as it meant more points, but that it didn't matter to him whether he would have to exercise vigorously or not. This is reflected in the fact that he regularly increased the difficulty level of the mini-games, confident that he could win at higher levels and thus achieve more points.

6.9.1.3 Activity Levels

As was seen from Table 6.17, Jack chose to play mini-games which facilitated a mixture of both light and more vigorous intensity physical activity. While the Collect the Coins game was generally played at a light to moderate intensity, Jack played it at a high intensity. As was shown previously in Table 6.9 on Page 112 (Section 6.5), Jack played nearly all mini-games at a MVPA level. Broken down by session he played 100% at MVPA session 1, 72.7% session 2, 78.6% session 3, and 100% session 4. Thus, despite spending a high proportion of his time playing a mini-game which can be played walking, Jack's enthusiasm and determination to earn points meant that he played it at a high intensity.

6.9.1.4 Motivation

Through observations, it was clear that Jack was one of the most motivated members of the class. This was confirmed in the post-evaluation questionnaire where he quantified his motivation as 8. Jack quantified his motivation to earn the most points in the class as 10, beat his friend's scores as 8, and simply earn points as 7. During the post-evaluation interview, when asked what made him try so hard, he stated, "It was mainly the competition I say, it was just fun having competition with friends". On one occasion Jack logged into iFitQuest as his friend, subsequently cheating in an attempt to get some of their points taken off. Although done in jest, it highlights the lengths he was willing to go to in order to beat his peers.

As previously stated, Jack also showed motivation to beat his own personal bests, in particular on the Mystery Games. He stated in the post-evaluation interviews, "also to beat my high score as well. Just the very challenge of improving on my performance". As Jack set high Mystery Game scores in session 1 and 2, during the latter parts of session 2 and 3, he had very limited success in beating his PB, failing on 6 of his 8 attempts. However, he remained determined and enthusiastic and in session 4 succeeded in beating all of his PBs. This commitment in the face of adversity can be explained through his high self-efficacy [9, 14, 15], as discussed in Chapter Eight.

6.9.1.5 Discussion

Jack is the epitome of someone who embraced iFitQuest, enjoying the game while using it to perform MVPA. What is particularly pleasing about this is the fact that Jack classed himself as only a casual gamer, with a high enjoyment of his traditional P.E. class. Jack may have therefore been predicted as someone who would become disinterested in an exergame and fall into the category of those affected by a 'novelty effect'.

Jack was highly motivated by competition, while also striving for improvement. Despite having a high percentage of failure with respect to beating his own PBs, he remained motivated towards that goal in each session. Discussed in Section 6.10.6 and at length in Chapter Eight, his goal commitment can be attributed to his high self-efficacy.

Jack also represents someone who altered their mini-game selection habits to suit their needs, avoiding games like Return the Sheep, as they represented non-optimal ways to gain points.

6.9.2 Case Study 2: Isla

The second case study focuses on Isla, a 14 year old female who, pre-evaluation, had a high exercise self-efficacy (2.875 on the PASS scale) and a high level of sporting ability. Isla also had a positive attitude towards P.E. and exercise, quantifying her enjoyment on both as 8. Although pre-evaluation Isla rated her fitness as 6, through both observations and interviews with her P.E. teacher, it was established that Isla was a talented athlete, who until recently had competed in athletics competitions.

Isla was not a regular gamer, stating that she never played video games, nor had she ever previously played an exergame.

Isla provides an interesting case study for a number of reasons. First of all, she was an example of someone who had hit the 'adolescent slump' in exercise participation. Despite being a talented athlete, with both a high exercise self-efficacy and a high opinion of exercise, Isla did not participate in any physical activity outwith her obligatory 55 minute P.E. class. In interviews she stated that she "just got bored" with her athletics and that she didn't have enough time for exercise. Isla represents someone with common physical activity barriers, which exergames could potentially help remove. However, as she was someone who did not enjoy video games, it is interesting to consider how iFitQuest would appeal to such a player.

During the evaluation, Isla displayed some interesting in-game behaviours. She was not interested in the aspect of competition, totally disregarding the points system. Instead, she utilised iFitQuest as a training aid, using it to track her performance. This manifested itself in some unique mini-game selection habits, discussed in Section 6.9.2.2.

6.9.2.1 Evaluation Overview

On the whole, Isla had a positive exergame experience. Although she had little interest in both traditional video games and exergames, she was enthusiastic in class and highly motivated during each session. Despite this, Isla quantified her enjoyment of the system as 5. She did however state that she wanted to play the game again as part of her P.E. class, saying, "because I like running and I think this is a good game for me". Despite her mixed post-evaluation scores, observations showed that Isla was enthusiastic during each session.

Table 6.18 provides the pre- and post-evaluation scores for Isla. Of note is her increase of 0.625 on the self-efficacy scale, above the previously discussed threshold of 0.5. Isla had only moderate in-game success in terms of winning mini-games (a 50% win ratio). However, as previously stated, Isla was ambivalent towards winning, losing or earning points. Interviews confirmed that improving within mini-games

Table 6.18: Isla's pre- and post-evaluation scores.

	Pre	Post
Self-reported fitness	6	7
Enjoyment of exercise	8	8
Enjoyment of P.E.	9	8
Self-efficacy	2.875	3.500
Enjoyment of exergames	4	3

provided her with the greatest source of motivation. She stated in the post-evaluation interview, "Losing didn't matter at all, it was all about the enjoyment of actually playing the games. Winning was good because it showed I was training properly.", which highlights the way in which she was unaffected by losing the games and used winning only as validation for her training. Additionally, as Isla had a peer group of like-minded peers, the vicarious and persuasive information she received would also contribute towards the positive change in her self-efficacy. Based on the importance of self-efficacy within physical activity interventions, it is positive to note that Isla showed a considerable increase post-evaluation.

In terms of the other categories, there was little change over the course of the evaluation. Isla showed a slight increase in her self-reported fitness, no change in her enjoyment of exercise, and slight decreases in her attitude towards P.E. and exergames.

6.9.2.2 Gameplay Patterns

As can be seen from Table 6.19, Isla most consistently played the Collect the Coins game. Of particular interest, Isla focused a considerable amount of her attention towards the Follow the Chicken game in session 2. In the post-evaluation interview Isla stated, "I used to run a lot so I treated the games like training; I wanted to improve my fitness.", and "when I found a game that was interesting, I just wanted to play that game over and over again".

This is particularly interesting in contrast to the previous case study Jack, who catered his session with the primary concern points earning potential. Isla saw iFitQuest as an entertaining training aid. Isla stated that once she found that she enjoyed Follow the Chicken, she wanted to play it until she saw her performance improve to a satisfactory level. Also of interest, Isla increased the difficulty of the mini-game on 4 of the 6 occasions available to her (on the other two occasions she

Table 6.19: Isla's session by session game selection habits.

	Session Number			
Mini-Game	**1**	**2**	**3**	**4**
Escape the Wolf	1	0	0	0
Collect the Coins	4	3	6	6
Follow the Chicken	1	9	0	2
Return the Sheep	0	0	0	0
Visit the Fields	2	0	0	0
Mystery Games	3	3	3	3

let the difficulty automatically decrease). This is despite the fact that she lost the mini-game on each of those 6 occasions. She stated in the post-evaluation interview that she liked to raise the difficulty of the games, "I liked the challenge of running at the higher levels, and the challenge of winning the games at the high levels".

This perseverance, despite in-game failure, as well as the confidence and willingness to challenge herself, can be linked back to her high self-efficacy [9, 14, 15]. Additionally, her perseverance towards her self-set goal of improving her performance can too be attributed to her high self-efficacy level.

6.9.2.3 Activity Levels

As was shown in Table 6.19, Isla chose to predominantly play Collect the Coins and Follow the Chicken, both of which are games that support a variety of PA intensities (see Table 6.10 on Page 113). Isla most frequently played Collect the Coins which over the course of the evaluation was played predominantly at a light intensity by the participants (59.3% of plays).

However, Isla was one of the participants that spent the greatest amount of time exercising at a MVPA intensity, Table 6.9 on Page 112 showing that she spent 62.5%, 85.7%, 88.9%, and 57.1% in MVPA during sessions 1, 2, 3, and 4 respectively. Thus, much like Jack, despite spending the majority of her time within games that could, and generally did, support lighter intensities of physical activity, Isla with her drive to improve performance still maintained high levels of MVPA.

6.9.2.4 Motivation

Despite having one of the lowest enjoyment scores, Isla showed good motivation and effort whilst playing the game. This is emphasised by the fact that she exercised predominantly at a MVPA intensity, in particular within games that could be played at lower intensities.

Isla drew her motivation from a desire to see herself improve at the games (as she described it, using the games as "training aids") and through general enjoyment of specific mini-games. In the post-evaluation questionnaire, Isla quantified her motivation levels as 6. She stated that she was motivated to play the game, but this was affected by the fact that the evaluation was run during the first class of the day, and as such she was usually still tired. She also stated that had the Mystery Games been even harder, she would have been more motivated to play them. Given that Isla had a background in athletics, it is not surprising that she enjoyed those most akin to traditional athletics.

When asked to quantify aspects of the system in terms of the motivation they provided, Isla rated 'trying hard to improve her fitness' as the most motivating aspect, with 'trying hard to improve her mini-game scores' as the second most motivating. The three least motivating aspects were 'earning points', 'beating her friend's score', and 'getting the most points in the class'. This is consistent with what she stated in the post-evaluation interviews, "I used to run a lot so I treated the games like training, I wanted to improve my fitness".

Isla, with her background in competitive athletics, was motivated partly through enjoyment, but also through a desire to improve her fitness and her performance within the games. She ignored ego-based motivators like competition and praise, and sought to master the task at hand. She did not concern herself with in-game success, other than as a means to validate her training.

6.9.2.5 Discussion

Isla provides a counter example to the previous case study Jack. Despite both having relatively high starting self-efficacy, and similar backgrounds in terms of fitness and physical activity participation, they both had notably different motivations. Isla was motivated by a desire to see herself improve, and through an enjoyment of particular mini-games, in contrast to the competitive nature of Jack.

One particularly interesting aspect of Isla's experience was the notable increase in her exercise self-efficacy. This a particularly positive finding, due to the impact of self-efficacy on physical activity participation and behaviour. Of interest is the fact that Isla did not necessarily enjoy the exergame experience, nor did she come out of the evaluation with a more positive outlook on exergames in general. One exergame is unlikely to be a long term solution to physical activity issues, with hardware and software giving any system a short shelf life. However, if an exergame can positively influence exercise self-efficacy, the players are more likely to partake in physical activity outwith the system, which would be a considerable success for an exergame.

Isla's behaviour within the game can be explained by her high self-efficacy (both pre- and post-evaluation). The way in which she set herself a goal of improving at a specific game, persevered towards this goal despite regularly failing, was unaffected by losing mini-games, and challenged herself at high difficulty levels, is consistent with Bandura's theories on self-efficacy [9, 14, 15].

6.9.3 Case Study 3: Daniel

The third case study focuses on Daniel, a 14 year old male with a mixed attitude towards exercise. Despite having high exercise self-efficacy (3.25 on the PASS scale) pre-evaluation, Daniel felt he had only a moderately good level of fitness (quantified as 6). Daniel also rated his enjoyment of exercise as 2, the lowest in the class.

Daniel described himself as an avid gamer, stating in the pre-evaluation questionnaire that he played "most days". Despite having previously played an exergame, Daniel stated that he didn't play them on a regular basis, although he did enjoy them (quantified as 7).

Daniel provides an interesting case study because he sits at extreme ends of the spectrum in terms of both enjoyment of exercise and video game play habits. Of all participants, Daniel was the least interested in physical activity pre-evaluation, but the most interested in video games. Daniel is therefore someone for whom exergames are hypothesised to be well suited, with the hope that through an enjoyment of the video game elements, his opinion towards physical activity could be positively influenced.

Daniel displayed some interesting in-game habits, choosing to play the mini-games that he appreciated most from a video game perspective. As someone who also had low interest in physical activity and a low starting fitness level, yet high exercise self-efficacy, Daniel provides an interesting opportunity to investigate the tension between high self-efficacy and low performance.

6.9.3.1 Evaluation Overview

As with the two previous case studies, and consistent with the general experience of the class, Daniel had a positive exergame experience. Given Daniel's high opinion of exergames pre-evaluation, it was somewhat disappointing that he rated his enjoyment of the iFitQuest evaluation as 6. In the post-evaluation questionnaire he could not provide a specific reason for this score, but did provide as a suggestion that the game should include more goals (the implications of this are discussed in the forthcoming sections). Daniel did however enjoy the experience enough to state that he would like to continue using the game within his P.E. class, and that it should be made available for purchase so that he could play it again during his spare time.

Table 6.20: Daniel's pre- and post-evaluation scores.

	Pre	**Post**
Self-reported fitness	6	2
Enjoyment of exercise	2	0
Enjoyment of P.E.	7	7
Self-efficacy	3.25	2.25
Enjoyment of exergames	7	7

Looking closely at Daniel's pre- and post-evaluation questionnaire scores, there are two particular aspects which merit discussion. First of all, Daniel's self-efficacy decreased over the course of the evaluation. As was discussed in depth during Chapter Two, this is a negative outcome given the importance of self-efficacy within physical activity interventions.

Additionally, Daniel rated his post-evaluation fitness as 2 on the scale between 1 and 10, the lowest in the class. While it is unlikely that iFitQuest actually decreased Daniel's fitness levels, a more favourable outcome would have been Daniel having a more positive outlook with respect to his level of fitness.

The discussion within the rest of this case study serves to help explain the possible reasons for these downturns in score.

6.9.3.2 Gameplay Patterns

As can be seen from Table 6.21, Daniel played a variety of mini-games over the course of the 3 sessions he attended. While Daniel chose to regularly play Escape the Wolf, Return the Sheep, and the Mystery Games, particularly interesting is the fact that he chose to generally avoid the Collect the Coins game, which is drastically different to the general behaviour of the class, and indeed the two previous case studies.

Table 6.21: Daniel's session by session game selection habits.

	Session Number			
Mini-Game	**1**	**2**	**3**	**4**
Escape the Wolf		0	7	5
Collect the Coins		0	1	1
Follow the Chicken		3	0	3
Return the Sheep		6	5	5
Visit the Fields		0	1	3
Mystery Games		2	6	5

Daniel's motivation for this behaviour is discussed within Section 6.9.3.4. In brief, he disliked the Collect the Coins game as he felt it lacked a clearly defined and meaningful goal. Daniel's motivation, which determined his in-game selection habits, was influenced by his gaming background.

Of the three mini-games that Daniel did enjoy playing, he stated in the post-evaluation interview that during a session he would select which of those to play "at random".

Another interesting aspect of Daniel's in-game habits was that after every mini-game, he chose to go back to the main menu, even on the occasions when he subsequently replayed the same mini-game (and thus could have bypassed the main menu by pressing the quick replay button). In the post-evaluation interview, it was established that this was due to his desire to constantly check his points total (which was accessed from the main menu). This behaviour highlights that Daniel also drew motivation for the points aspect of iFitQuest.

6.9.3.3 Activity Levels

Highlighted in the previous section, Daniel was one of participants who, over the course of the evaluation, played the greatest variety in mini-games. In Table 6.9 on

Page 112, Daniel stands out as undertaking MVPA less frequently than many of the the other participants in the evaluation. Having missed session 1, Daniel undertook 36.4% MVPA in session 2, 33.3% in session 3, and 40% in session 4.

Observations were consistent with the log-file data. While Daniel was capable of exercising at a MVPA intensity, he spent the majority of his time at lower intensities. He did however spend very little time completely sedentary, log-files showing that he spent only short periods of time in between mini-games, and observations highlighting that in comparison to his peers, he less frequently stood comparing scores or socialising.

Interviews with his class P.E. teacher confirmed that Daniel was usually one of the least active in the class, generally participating in traditional P.E. lessons enthusiastically and with effort, but expending little energy.

For Daniel, it is possible to conclude that iFitQuest successfully facilitated and motivated him to participate in physical activity. Based on the P.E. teacher's expert observations, relative to his performances during traditional P.E. classes, iFitQuest likely facilitated more frequent MVPA than he would have undertaken normally. Due to his mini-game selection habits, he also spent very little time sedentary, a successful outcome given his low fitness level pre-evaluation.

6.9.3.4 Motivation

Daniel displayed interesting behaviour in terms of his motivation while playing iFitQuest. In his post-evaluation interview, he stated that there were two particularly important factors. On one level, he was motivated by earning points and a desire to compete with his peers. He stated, "I just liked earning points. Mostly I like comparing with friends". This was confirmed by observations during the sessions, in which Daniel regularly discussed with the observing researchers his concern that his points total was not updating properly and therefore he was losing out on the points he was earning.

Despite the above, Daniel selected which games to play based not on his desire to earn points, but on the goals within the mini-games. He stated that despite identifying you could earn more points for less effort within the Collect the Coins mini-game, he was more motivated to play the Return the Sheep mini-game. He stated, "I prefer the sheep game, as there was a clear goal, it had a point", further adding "because why would you collect coins when you cannot spend them". Therefore, despite having the motivation to earn points much like Jack, this did not override his desire to play the mini-games that mattered most to him. The need for a clear and meaningful goal was of more importance to Daniel. This was confirmed in the post-evaluation questionnaire. In answer to the question,"Can you think of changes to the game that would make you more motivated to play it?", he stated that the game needed "more goals".

Daniel quantified his motivation level while playing iFitQuest as 8, which is consistent with observational data, and the log-file data that showed his desire to quickly play mini-games with minimal breaks. Consistent with his interview, Daniel identified within the post-evaluation questionnaire "Trying hard to beat his friends score", "Trying hard as he simply enjoyed the games", and "Trying hard to come top of the class points leaderboard" as the three most motivating factors.

6.9.3.5 Discussion

Of particular interest with Daniel was his mini-game selection behaviour, in particular the way he required concrete and meaningful goals within the mini-games. This highlights another disparate motivation when compared to the two previous case studies. Daniel's desire for concrete goals does however highlight that the flexibility of iFitQuest may not be optimal for those players that desire more structure.

Like Jack, Daniel was also motivated by the points system and the way it could be used to compete with friends. Although Daniel's actual performance was lower than his peers, competition remained an important motivator. While motivated by competition, Daniel did not let it dominate his experience, in contrast to Jack. While earning points was important, it did not override his desire to play the games he enjoyed, and felt had meaning.

Related to this, and of greatest concern with respect to Daniel, is that his self-efficacy score was considerably lower post-evaluation. As Bandura's work highlights, past performances and vicarious information are important factors in establishing self-efficacy [12]. As Daniel was motivated by competition yet regularly teased by his peers for his low points total, the vicarious information received, and judgement of past performance may explain why Daniel decreased his self-efficacy. His lower self-efficacy may also explain his lesser goal commitment, in terms of the fact that he was not as driven to earn points in the same way that Jack was.

As for the large decrease in self-reported fitness, the P.E. teacher explained pre-evaluation that the children were trained to evaluate their own fitness levels. It is possible that pre-evaluation, Daniel had a high opinion of his own fitness levels, which were subsequently lowered based on in-game shortcomings, as well as failures in terms of competition with his peers. While competition was a motivator for Daniel, the way in which it negatively influenced his opinion of himself highlights its potentially problematic nature within exergames.

6.10 Discussion

This section provides the preliminary discussion of the first school-based iFitQuest evaluation. While the primary discussion is reserved for Chapter Eight, this section revisits the research questions investigated during this chapter.

6.10.1 Is iFitQuest enjoyable to play?

Based on the results of this evaluation, it is possible to conclude that iFitQuest is a generally enjoyable exergame. The median and modal self-reported enjoyment score was 6.0 (mean 6.3, scale of 1 to 10), with the majority also wanting to continue using the game in their P.E. class. The post-evaluation questionnaire provided insight into mini-game preferences, and despite the fact that the Collect the Coins and the Mystery Games were clear favourites, the variety in preferences across the mini-games is testament to the disparate nature of interests, and the fact that a suite of games provides opportunity to a variety of players. The reasons for liking and disliking games (outlined in Tables 6.7 and 6.8) highlight the importance of simple game mechanics, games that are fun to play, easy to understand, with clear goals, and strong themes.

Although the statistical tests must be tentatively interpreted, the gender of the participant appeared to have no statistically significant impact on their enjoyment of the experience. This is in contrast to the findings in Chapter Four, which highlighted that males generally enjoyed the prototype versions more than their female peers. While further evaluation is required to confirm these findings, it appears iFitQuest is capable of appealing to players of both genders.

6.10.2 Is iFitQuest physically demanding?

It is possible to conclude from the results presented within this chapter that iFitQuest successfully facilitates physical activity at all levels of intensity. Each mini-game was capable of facilitating a target intensity, while also supporting a range of physical activity intensities. It is positive to note that iFitQuest was capable of facilitating MVPA. Therefore, for the majority of players, playing iFitQuest was contributing towards their daily physical activity targets. Additionally, for those not capable of higher intensity physical activity, iFitQuest provided a platform to avoid sedentary behaviours. Isla, and Daniel, two participants who at the time did not participate in physical activity, embraced iFitQuest and utilised the game towards achieving their PA guidelines.

The pre- and post-evaluation quantitative statistics highlight that any actual physiological improvements to fitness were likely minimal. However, over the course of a short intervention, with fairly short periods of game time, this outcome was not unexpected. In the next Chapter, a further study is discussed which looks at a more formalised method of measuring the way iFitQuest can influence fitness, and the way in which it facilitates physical activity.

One limitation of this evaluation is the method used to establish physical activity intensity. As stated, intensities were calculated using the average speed at which participants played mini-games. This is potentially flawed for a number of reasons. While researchers have looked at how mph can be converted to physical activity intensity, the approach is a ‘rule of thumb’, and is not a scientifically valid method of measuring energy expenditure, like for example, heart rate monitors. The method also loses detail, as any activity done outwith mini-games is not considered. Additionally, the method considers mini-games in their entirety. For example, a person may sprint for 5 seconds, and then stand sedentary for 15 seconds, giving a moderate intensity average speed which is not consistent with behaviour. While these limitations are acknowledged, the method provides a valuable insight, especially when combined with the observations of the expert P.E. teacher. In the next chapter, an evaluation using tri-axial accelerometers is discussed, in order to establish a more accurate picture of the physical activity undertaken while iFitQuest.

6.10.3 Is there a novelty effect within the iFitQuest system?

As this study represented the first prolonged evaluation of iFitQuest, it is positive to note that based on the results presented within this chapter, a novelty effect was not observed. Through an analysis of player opinion, and the way in which the participants performed physical activity within each session across the evaluation, it is possible to conclude that the majority of participants remained motivated by iFitQuest. In fact, the results suggest that the final session was actually the most productive for the class, and that had timetable constraints not been present, the participating class would have continued to positively use the game within their P.E. class.

While the results presented within this chapter are positive with regards to a novelty effect, it is not possible to conclude that iFitQuest is immune to such a phenomenon based only on a 5-week (4 session) evaluation. To provide further discussion on novelty effects, in Chapter Seven the concept is revisited within the context of a 7-week evaluation.

6.10.4 What is there to learn about the exergame experience through prolonged play?

Given the flexibility afforded by the system, it is particularly pleasing to note that the most enjoyed and frequently played mini-games were also the most physically demanding. Rather than avoid the most physically intense mini-games, players were often drawn to them, enjoying the challenge that they provided. This highlights the positive way in which iFitQuest can motivate participants to exercise.

By looking in detail at the motivation levels of the participants, and the factors that contributed to such motivation, the design requirements which focussed on 'flexibility', 'open-play', and the large number of potential 'micro- and macro-goals' were validated. Designing the system in this way helped iFitQuest appeal to a wide variety of participants. Further to this, the lack of novelty effect highlights that at least over the course of a 5-week evaluation, it is possible to maintain motivation levels in the majority of participants through a game like iFitQuest.

The case studies also highlight the way in which the background of the player, in particular their self-efficacy, interacts, influences and affects the motivation of the participant and their subsequent in-game behaviour. Isla remained motivated and committed towards her goal despite experiencing a number of in-game losses, even having the motivation to challenge herself at the highest levels of the game. Jack remained motivated by his goal of earning points and beating his peers, to the extent that he exercised vigorously within all the mini-games he played, and he chose which mini-game to play based solely on the potential points he could earn. In Chapter Eight, these case studies are revisited along with cases from the other prolonged iFitQuest evaluation to draw stronger conclusions on the effect of self-efficacy within iFitQuest.

6.10.5 How does iFitQuest fit within the school context?

Based on the positive opinion of both the participants and the school teacher, as well as considering the physical activity facilitated by the game, and the lack of novelty effect observed, it is possible to conclude that iFitQuest was well suited to this particular school context.

Worth particular mention is the way in which many of the design requirements positively affected the experience. The 'flexibility' of the system meant that the game worked well despite the flexible length of the sessions. The 'quick start' and 'short bursts' requirements helped ensure maximal exposure to physical activity despite the constraints of the school timetable.

The design requirements were also particularly well suited to allow for a mixed-ability class to get the most from the evaluation. There was evidence of players who primarily played light intensity games, while others focussed on the higher intensity games. Data showed that even within a single mini-game, through the level design and flexible nature, whole ranges of physical activity intensity could be facilitated. There was also a variety of in-game motivations, while some of the class focussed on competition, others focussed on task-mastery. iFitQuest was capable of targeting a variety of players, proving well suited to the demands of a school context.

6.10.6 Case Study Conclusions

The case studies gave additional insight, supplementing the higher level findings and providing the foundations to better understand the exergame experience.

The case studies highlight in detail the way in which different players could cater the system to suit their needs.

The contrasting motivational factors were also apparent through the case study analysis. Where as Jack was motivated by a desire to win, and compete, Isla was driven on by the challenge of improving her fitness. The 'gamer' Daniel, while motivated by points and competition, found appeal in the gameplay aspects of the system, such as the level up feature and the goal of the Return the Sheep game.

Importantly, the way in which self-efficacy plays a role on the exergame experience was also evident. Within Chapter Seven, further examples on the influence of self-efficacy are provided. These examples are then combined within Chapter Eight for a full discussion on the role of self-efficacy.

6.11 Summary

This study represented the first investigation of iFitQuest over a prolonged period of use. Set within a mixed-ability high school class, 14 adolescent participants took part in a 5-week (4 session) exergame intervention.

Having evaluated prototypes of iFitQuest twice before within single session evaluations, the purpose of the study was to investigate the final system, and importantly begin answering the fundamental research questions which require the element of 'time'; such as the potential of novelty effects, and a better understanding of the exergame experience.

Through this evaluation, it was possible to begin drawing conclusions on the success of the iFitQuest system. Not only was the game generally enjoyable to play, physically demanding, and motivating, it also withstood a novelty effect.

Further to this, the design requirements outlined in Chapter Five were evaluated for the first time, both in terms of how effectively they were incorporated into the system and how they contributed towards the success of the evaluation. The disparate nature of the participants' in-game behaviour, such as motivational factors, physical activity intensities, and mini-game selection habits, all highlight the successful way in which iFitQuest can appeal to a varied demographic. Additionally, the 'focussed activities', 'short bursts', and 'quick start' requirements all helped to ensure that the game was well suited to the constraints of a high school context.

However, while this evaluation was a success, generalisations cannot be made without further evaluation. This evaluation, while more longitudinal in nature than many exergame interventions, lasted only 4 sessions, with a relatively small sample size. Thus, to add to the above evidence, and provide further insight into the exergame experience, an additional evaluation was undertaken.

In the next chapter, a 7-week study at a primary education school is outlined. In Chapter Eight, the overall discussion, relating points from both evaluations, is then presented.

CHAPTER 7

Evaluation 2: 7-Week Primary School Evaluation

In the previous chapter, the first prolonged evaluation of iFitQuest was presented and discussed. By evaluating over a period of time, and allowing participants to play the game on multiple occasions, it provided the first opportunity to investigate in greater depth the success of iFitQuest. In particular, whether it suffered from a novelty effect in terms of maintaining motivation, enjoyment and physical activity. The evaluation also provided the first opportunity to fully investigate the in-game behaviours of the participants, in particular the way in which self-efficacy affected the exergame experience.

The results presented in the previous chapter were generally positive. iFitQuest successfully facilitated physical activity within an enjoyable and motivating context. In order to begin generalising, and building upon the findings, further evaluation was required. By investigating iFitQuest with a greater number of participants, it mitigates the risk that findings were unique and not recurring phenomena. Further to this, due to the fear of participant drop-outs, this additional evaluation was scheduled to protect against the risk of small sample sizes.

In this chapter, the second principal evaluation of the iFitQuest system is outlined, a 7-week long multiple session evaluation conducted within a primary education context. This evaluation provided an opportunity to evaluate iFitQuest within a contrasting school context, and with a younger demographic of adolescent children. Additionally, the more prolonged nature of the evaluation allowed for greater insight into the exergame experience of the participants.

This chapter is organised as follows; first, the purpose of the evaluation is formalised through an overview of the research questions. The chapter then moves on to describe the evaluation, culminating in a series of case studies intended to emphasise the interesting in-game behaviour of the participants. There is then a short discussion and summary, with the primary discussions occurring within Chapter Eight.

A published account of this evaluation is available in Macvean and Robertson [122].

7.1 Purpose

At a general level, the purpose of this evaluation was two-fold: *a*) to re-investigate the phenomena identified during the previous evaluation with additional participants; and *b*) investigate the success of the system with a younger demographic, and within a different school context. With regards to the first point, the purpose was to add further weight to the conclusions of the previous evaluation, and begin to further generalise the results. In addition to this, while the different context and participant ages meant that no direct comparison was possible between evaluations (i.e. the results cannot be pooled for statistical tests), this evaluation provided an additional avenue to investigate the in-game behaviour of the participants and find commonalities in behaviour between the two studies. Further to this, by conducting another prolonged evaluation, of greater length and play frequency, it provided further opportunity to investigate the notion of a novelty effect.

Once more, the purpose of this evaluation was to contribute towards the following principal research questions:[1]

RQ 1. To what extent can a location-aware exergame played within a school-based context promote physical activity, while remaining enjoyable and motivating?

RQ 2. Which features and elements of iFitQuest contributed towards the exergame experience of the participants, and the overall success of the system?

RQ 3. To what extent can self-efficacy be utilised to understand and explain the exergame experience?

These research questions can be broken down in to the following sub-questions:[2]

7.1 Is iFitQuest enjoyable to play?

7.2 Is iFitQuest physically demanding?

  (a) Can iFitQuest facilitate prolonged PA?

  (b) Can iFitQuest facilitate a range of PA intensities?

  (c) Can iFitQuest improve the fitness level of the participants?

[1]A Research Question Schema can be found in Appendix G, which highlights how each sub-question relates to the three overarching principal research questions.

[2]Research Question 7.1 through 7.4 are identical to the corresponding questions in Chapter 6. They are designed to reinvestigate the phenomena identified during the prior evaluation. Research Question 7.5 onwards represent new directions of investigation based on the findings of the prior evaluation.

7.3 Is there a novelty effect within the iFitQuest system?

7.4 What is there to learn about the exergame experience through prolonged play?

   (a) Does player behaviour change with time?

   (b) How does the self-efficacy of the participant affect their experience?

   (c) What can be learned about players' in-game motivation?

The previous evaluation, in particular with regards to the case study analysis, began to highlight the influence of self-efficacy on the exergame experience. Based on the findings of the previous evaluation, and the understanding of the related literature, it was possible to construct more detailed research questions for this evaluation:

7.5 How does the self-efficacy of the participant affect their mini-game selection habits?

   (a) How does the self-efficacy of the participant influence replay or avoid behaviour?

   (b) How does the self-efficacy of the participant influence their difficulty level setting?

7.6 How does the self-efficacy of the participant affect their goal setting?

7.7 How does the self-efficacy of the participant affect their goal-commitment?

7.8 How does the self-efficacy of the participant affect their reaction to success or failure?

With regards to the second primary purpose of this evaluation, the new context allowed for the following research questions:

7.9 How does the primary school context affect the experience?

7.10 Is iFitQuest appealing to a younger demographic?

7.11 Do the design requirements of the iFitQuest system fit within the primary school context?

7.2 Method

In Chapter Six, Section 6.1, the methodology for the two principal evaluations of this thesis was discussed. A mixed-method approach was adopted, with the goal of collating data from various sources to avoid reliance on low powered statistical tests. The culmination of the mixed-methods approach is a series of case studies, with each case focussing on a single participant, built using interviews, questionnaire data, observations, and in-game log-files.

7.2.1 Data Gathering

In general, the same data gathering techniques adopted for the previous evaluation were adopted for this evaluation. These were as follows:

1. Pre- and Post-evaluation questionnaires.
2. In-game log-files.
3. Researcher observations.
4. Expert observations.
5. Case-study interviews.

There were, however, some minor changes for this evaluation. First of all, the expert observations which were conducted by the class P.E. teacher during the previous evaluation were conducted by a full-time classroom teaching assistant for this evaluation. As this evaluation occurred outwith a timetabled P.E. class, no classroom P.E. teacher was available. Thus, the expert for this evaluation did not have a background in physical activity. Instead, she was in an position to comment on the attitude and commitment of the participants, and due to a more intimate relationship with the children, gather more personal information with regards to attitude towards the system and their general evaluation experience.

Second of all, the researcher observations were less frequent for this evaluation due to the more flexible context. A researcher was present for 9 of the 12 sessions, with the other sessions occurring at short notice.

In addition to the above data gathering methods, two additional methods were adopted with the specific aim of answering Research Questions 7.1. Is iFitQuest physically demanding?:

6. Accelerometer data.

7. Pre- and Post-evaluation fitness test.

As a one-off during the final session of the evaluation, physical activity data was gathered using *ActiGraph* tri-axial accelerometers. These devices provide more accurate physical activity data than is possible on an iPhone, however they were only available for one session. The accelerometers provide highly validated information on the amount of physical activity the participants were undertaking [173, 207], providing the clearest possible picture of the way iFitQuest facilitates physical activity, in particular a clear breakdown of time spent at different intensities of physical activity.

One additional hope for this evaluation was to measure quantitatively the way in which iFitQuest affects the fitness levels of the participants. In order to allow for this, a pre- and post-evaluation fitness test was administered in order to establish whether there was any measurable improvement in the fitness of the participants. It was decided that the *Bleep Test*, also known as the *Multi-Stage Fitness Test* [112], would be adopted for this purpose. The Bleep Test involves repeated 20-metre shuttle runs done at an ever increasing pace, dictated by a 'bleep' played through a stereo system. The participant must run until exhaustion, or until they fail to complete one shuttle in the designated time. The participant is then assigned a score which reflects the number of full shuttles they completed. Bleep test scores range between 1.1 and 20.14, with children expected to fall within the range of 1.1 and 10.9. Higher scores represent a greater distance travelled and thus a higher level of fitness. The Bleep Test was chosen due to its regular use for fitness testing within schools. The participants of this evaluation had recently participated in the test during their P.E. class, meaning that there would be no practice tests or training required before the results became usable.

7.2.2 Participants

The participating class was a Primary Seven class at a local primary education school in Scotland. In total, the evaluation involved 12 pupils (one complete class), aged between 11-12 years old (mean = 11.42, median = 11). The class was comprised of 8 females and 4 males. The participating class were volunteered by their class teacher, who responded to an email call for participation due to her existing interest in physical activity and technology. As with the previous evaluation, the children were all given a trial play of the system before they decided whether they wanted to opt into the evaluation. While they were encouraged by their teacher to participate, they were free to individually opt out at any stage in the evaluation process. Again, full ethical approval was granted by the Heriot-Watt University Computer Science ethics process, and individual consent was sought from all participants, as well as their parent or guardian. Ethical forms are contained within Appendix A.

Table 7.1: Pre-evaluation self-reported scores.

Name[3]	**Gender**	**Fitness**	**Enjoy Exercise**	**Enjoy P.E.**	**Enjoy Exergame**	**Self-Eff.**	**Bleep Test**
Abigail	F	9	8	6	7	2.625	2.8
Holly	F	7	8	1	9	3.250	2.2
Ben	M	5	10	8	8	3.500	2.7
Anna	F	6	6	10	2	3.375	3.1
Nick	M	8	10	10	10	3.375	5.2
David	M	8	10	10	1	3.500	5.2
Alice	F	6	9	7	10	3.500	2.4
Olivia	F	7	6	2	6	2.000	2.7
John	M	7	6	8	4	3.500	4.6
Hannah	F	5	5	10	3	2.500	2.7
Jennifer	F	9	7	10	9	2.000	2.2
Mia	F	6	9	8	10	2.750	2.2

As the participants came from a whole primary school class, they represented a wide variety of attitudes towards physical activity and exergames, as well as providing a diverse range in terms of fitness levels and exercise self-efficacies. In the pre-evaluation questionnaire, participants were asked to self-report scores for fitness level, enjoyment of exercise, enjoyment of P.E., and enjoyment of exergames, each on a scale of 1 to 10. As with the previous evaluation, despite the class teacher stating that fitness levels were mixed, and generally poor, the class self-reported median fitness levels of 7.0, mode of 6.0 / 8.0, and mean of 6.92 (sd = 1.38, range = $5-9$). Again, despite the teacher's observation that the class had mixed attitudes towards physical activity and P.E., the class self-reported high enjoyment levels for both exercising (median = 8.0, mode = 6.0 / 10.0, mean = 7.83, sd = 1.80, range = $5-10$), and P.E (median = 8.0, mode = 10.0, mean = 7.5, sd = 3.12, range = $1-10$), although in both instances the range highlights some outliers with differing opinion. As a final measure, once again the Pender instrument [159] was used to establish the pre- and

[3]Pseudonyms used for anonymity.

post-evaluation self-efficacies of the participants. The mean pre-evaluation score for the participants was 2.99, with the median score = 3.3 (sd = 0.59, range = $2.0-3.5$). Compared with the evaluation outlined in Chapter Six, the pre-evaluation self-efficacy scores were very similar (mean = 2.789, sd = 1.875, range = $1.875 - 3.375$).

As was discussed in Section 7.2.1, a formalised fitness test was conducted as a means to measure the participants' pre- and post-evaluation fitness levels. The pre-evaluation scores confirmed the teacher's opinion that the class was of mixed ability, with generally low levels of fitness. The mean Bleep Test score was 3.2 (rounded to the nearest complete level), with the males on average scoring higher than the females (4.4 versus 2.5). According to Sandercock et al. this represents below average scores for both males and females at this age range [180].

Table 7.2 highlights the diversity of gaming backgrounds, and in particular, the experience of the class in playing exergames.

Table 7.2: Participants' gaming background.

Description	**Video game Frequency**	**Exergame Frequency**
Never	3	3
Once or twice per week	3	6
Most days	4	3
Everyday	2	0

7.2.3 School Profile

The school selected for this evaluation was a state-run primary education school in the North of Edinburgh. Primary schools support the education of children from the ages of 4-5 (age at the start of Primary One) to 10-11 (age at the start of Primary Seven). The school was located within a historically industrial area of lower socio-economic status.

A recent school report outlined that attainment levels of pupils was low, with many failing to reach national standards [60]. This was important when considering the application of the questionnaire, given that those participating in the evaluation were likely below average literacy.

The school has a concrete playground, with no access to a grass playing field. The evaluation was therefore conducted within the school grounds on the concrete playground. This had the advantage that it was more accommodating than grass in adverse weather conditions, but it represented a potential risk in terms of injury should a player fall.

7.2.4 Procedure

The evaluation consisted of 12 sessions spread over 7-weeks. The iPhones were provided to the class teacher, in order to allow her to play the game whenever time allowed, although she made a commitment to allow for between 1 and 3 play sessions per week.

Once more, the length of the evaluation was dictated by the school calendar, with the study lasting the latter part of the summer term, commencing after the spring holiday break, and ending on the last day of the school year. The evaluation was designed to be of greater length than the previous evaluation, in order to further evaluate the potential of a novelty effect, as well as allowing for more time to understand and explain the exergame experience. Seven weeks represented a longer evaluation than the majority of other prolonged exergame evaluations [115, 204, 229, 230] and of a length equivalent to, and in some cases greater than, some successful traditional school-based physical activity interventions [189]. The length of study was also comparable to the blocks of time spent on any single activity within traditional P.E. classes, which is generally between 6-8 weeks.

The number of sessions played was dictated by the constraints of the school curriculum and the weather conditions. Ideally the teacher had hoped to use the system more, but she successfully met her commitment of allowing at least one play per week; 4 weeks contained one play, 1 week contained two plays, and 2 weeks contained three plays.

Unlike with the previous evaluation, there was no timetable constraints, due to the more flexible nature of a primary education context. Thus, the exact day, time and length of each play was variable. The teacher ensured that each game was between 20 and 30 minutes in length. This was chosen as it mirrored the length of time usually dedicated to class P.E., potentially allowing for fitness gains while also considering the attention span and motivation of the younger participants. It is worth noting that 20 to 30 minute sessions, between once and three times per week, is consistent with many other school-based physical activity interventions [189].

As the pupils were given a trial session, this provided the class with an opportunity to learn how to use and play iFitQuest, allowing the study to properly begin on the first session. Note, this trial session is not considered as one of the 12 sessions, and no data from that session is included within this analysis.

Unlike with the previous evaluation, the structure to the sessions was less formal. There was no formal initial briefing or debrief during each session, although children still did a non-iFitQuest warm-up with the learning assistant before playing the game. On the days that a researcher was present, informal interviews were conducted before and after the session to establish how the players felt towards the game. Games were played outside in the school playground, where traditional P.E. classes were held as well as break-time recreational activities. Unlike with the previous evaluation, the iFitQuest evaluation did not replace the traditional P.E. lessons of the class, which continued to be held once per week on a day iFitQuest was not being played.

The final iFitQuest session was used to gather accelerometer data, as was discussed in Section 7.2.1. The session was run as normal, with the addition that the children were asked to wear accelerometers around their waist. As this was the final session, attendance was poor (due to the impending school holidays), and as such the children were told that any points earned would not contribute towards their evaluation totals. The implications of this on the motivation levels are discussed in Section 7.4.

Post-evaluation, two separate debrief sessions were conducted, on two consecutive days following the final session. During the first session, the participants completed the post-evaluation questionnaires. During the second session, formal interviews were held with 6 of the participants, a semi-structured group discussion was held, after which a small prize-giving was conducted to thank the class for their participation.

7.3 Results

7.3.1 Overview

Over the course of the 7-week study, iFitQuest was played on 12 separate occasions. Across all participants, it was played 103 times, averaging as between 8 and 9 plays per person (median = 9, mean = 8.58). Two participants were present for all 12 sessions. The least number of plays was from two participants, who were present for four sessions. These absences were caused in one case by an exclusion due to bad behaviour, and in the other, a serious injury (occurring outwith iFitQuest) preventing any form of physical activity.

The mean length of an iFitQuest game was 19 minutes and 45 seconds. When the non-game based warm-up and warm-down are considered, this brings the total session time within the 20 to 30 minute range planned for the trial. The longest mean iFitQuest session was the 8th play, when the game was played for an average time of 25 minutes and 29 seconds (not including warm-up and warm-down). The shortest session was session 9, when the mean play time was 10 minutes and 19 seconds. This was due to adverse weather resulting in an early finish to the session. The mean game length is calculated by looking across all participants present on the day of the session, as all participants have slightly different in-game times due to the logistics of handing out the devices, and logging-in to the game.

Over the course of the evaluation, a total of 1580 mini-games were played. The breakdown of this is presented within Table 7.3.

Table 7.3: Overall number of plays for each mini-game across the evaluation.

Mini-Game	**Plays**	**%**
Collect the Coins	737	46.7%
Mystery Games	402	25.4%
Escape the Wolf	231	14.6%
Follow the Chicken	95	6.0%
Return the Sheep	68	4.3%
Visit the Fields	47	3.0%

7.3.2 General Experience

Overall, iFitQuest was well received by the class. The 12 participants self-reported their enjoyment with a median of 6.5, a mode of 5.0, and a mean score of 6.83 (sd = 2.1, range = $4 - 10$)[4]. Hannah stated that she "thought it [iFitQuest] was fun and exiting", while Alice stated she enjoyed the fact "you got lots of exercise and it was fun". Of the 12 participants, 8 stated that they would like to play the game again within a similar context (66.7 %), while 4 stated that they would not. Of those that stated they would not like to use the game again, Nick stated it was because he did not like the game, while Ben stated "it was boring".

Participants were also asked to rank in order of preference each of the 6 mini-games contained within the iFitQuest suite (with the Mystery Games classed as a

[4]Note, as with the previous evaluation, all quantitative statistics were provided through a rating scale between 1 (low) and 10 (high) unless otherwise stated.

single game due to the way it was presented on the interface). Table 7.4 presents the preferences of the participants. Note, due to one participant misunderstanding this question in the questionnaire, their data is excluded.

Table 7.4: Participants' mini-game rankings.

	Participant Number										
Mini-Game	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Escape the Wolf	3	4	4	3	3	2	6	3	3	1	4
Collect the Coins	1	1	1	5	1	1	1	2	2	4	1
Follow the Chicken	5	5	5	1	3	3	3	4	4	2	3
Return the Sheep	6	5	6	1	6	5	3	6	5	4	2
Visit the Fields	4	3	3	3	3	6	6	5	6	4	6
Mystery Games	1	1	2	6	1	4	1	1	1	2	5

As can be seen from Table 7.4, there was a strong preference towards the Collect the Coins game and the Mystery Game, with Return the Sheep and Visit the Fields consistently ranking amongst the lowest for the participants. The above preferences are generally consistent with the overall mini-game play frequency presented within Table 7.3.

Despite these clear preference, all of the mini-games with the exception of the Visit the Fields were someone's favourite game, while the Collect the Coins and Mystery Games also ranked lower for two participants. As with prior evaluation, this emphasises the need to cater for a diverse range of interests and supports the decision to develop iFitQuest as a suite of mini-games.

Many participants identified the points system as a key factor in selecting their favourite mini-game, with a number choosing Collect the Coins due to the fact it was the easiest way to earn points. The most common reason for disliking a game was its difficulty. Participants regularly identified a mini-game being too hard, or too confusing, as a key factor behind their decision. A greater insight into mini-game selection habits and preferences is presented within the Case Studies (Section 7.8).

7.4 Physical Activity

In the previous evaluation, one facet of the physical activity analysis was an investigation of how each of the different mini-games facilitated physical activity, in particular the ranges of physical activity intensity facilitated. As the previous evaluation confirmed that each mini-game could facilitate a range of intensities while some also generally focussed on one particular intensity, it was felt that there was no need to replicate these findings once more.

However, it was still important to investigate the amount of physical activity each participant undertook while participating in the evaluation to establish how iFitQuest faired within the new context and with a younger demographic.

In terms of self-reported physical activity, the participants felt they had a moderate to high workout during the evaluation, quantifying their level of physical activity with a median of 6.0, a mode of 4.0 / 5.0 and a mean of 6.4 (sd = 2.19, range = $4 - 10$).

By using the average speed at which each participant travelled within each mini-game they played (as was used and explained within the last evaluation), it was again possible to establish an estimate of how much physical activity each participant got whilst playing iFitQuest, broken down by session. This is shown in Table 7.5. Note, a shaded cell represents a session missed by the participant.

Table 7.5: Percentage of MVPA mini-games for each participant split by session.

	Session Number											
Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Jennifer			69	74	45	35	24		18	44	30	
Olivia	56	67	30	20	54	25	29	29	12	19	8	13
Hannah	53		43	15	26	15	20	17	0	25	33	36
Abigail	54		40	33	26	27	42	45	50	35	24	
Mia			86	90	54			41	43	32		8
Holly	62		54	39		67	43	39	30	66		55
Anna	55	67	69	50	43	20				45	29	75
Nick	73	36		40		0						
Ben	43	20	20	9		22						64
David	65	100	77	46	27	29	25	32	50	41	33	29
Alice	74		57	67	56	53	42	37	45	38	65	29
John					58		72		40			75

While Table 7.5 is more detailed than the corresponding table in the previous chapter (due to the fact there were 3 times more sessions), the general picture is the same. As can be seen, iFitQuest promoted MVPA in each of the 12 participants. Of the 103 sessions, there were only two examples of someone playing the game at an intensity which promoted no MVPA. Thus, in the majority of cases, iFitQuest facilitated physical activity which contributed towards the players' daily physical activity targets. Crucially, the table highlights a general decline in higher intensity PA towards the latter sessions of the study, which is discussed in depth within Section 7.6.

In addition to the above MVPA data, in the final session of the evaluation, participants were provided with ActiGraph tri-axial accelerometers as a means to record well validated data on the way iFitQuest facilitated physical activity[5]. By measuring the movement of the participant for the duration of the an iFitQuest play session, rather than confined only to the player's movement within the mini-games (and thus discounting movement done between mini-games), the accelerometers provide the most accurate account of in-game physical activity. In Table 7.6, this data is presented for the 8 students for which valid data was gathered (there were 9 students present during the session, but one accelerometer failed to record data).

Table 7.6: Accelerometer data showing PA activity breakdown by participant.

	Play Time (Minutes)					**Breakdown (%)**			
Name	**Total**	**sed**	**light**	**mod**	**vig**	**sed**	**light**	**mod**	**vig**
David	22.25	3.5	11	2.25	5.5	15.7	49.4	10.1	24.7
John	20.5	1.25	5.5	2.25	11.5	6.1	26.8	11.0	56.1
Olivia	24.25	3	17.5	1.5	2.25	12.4	72.2	6.2	9.3
Alice	20.0	4.0	12.75	1.0	2.25	20.0	63.8	5.0	11.3
Ben	18.0	2	12.5	1.25	2.25	11.1	69.4	6.9	12.5
Hannah	22.0	3.25	10.5	3	5.25	14.8	47.7	13.6	23.9
Mia	22.5	3.5	12.75	3.0	3.25	15.6	56.7	13.3	14.4
Anna	27.5	4.25	19	2	2.25	15.5	69.1	7.3	8.2

As can be seen from Table 7.6, the accelerometers confirm iFitQuest facilitates a range of physical activity intensities, with all 8 participants undertaking light, moderate and vigorous intensity physical activity during a session. Additionally, for participants such as John, and to a lesser extent Hannah and David, iFitQuest is capable of facilitating large portions of MVPA intensity PA, showing that playing the game can contribute towards daily PA targets. In the case of John, one session was enough to

[5]The ActiGraph data was analysed using the measurement thresholds recommended by Evenson et al. [65]. To summarise, the accelerometers return a measure of movement over each axis, split into 1 second epochs. Based on the amount of movement in any given epoch, the intensity of physical activity can be calculated based on Evenson et al's. guidelines [65]. The data can therefore be used to establish the amount of time a participant spent in the different physical activity intensity zones over the course of the session.

complete over 13 minutes of MVPA. The above data also highlights that some players spend the majority of their time within the light intensity threshold, such as Olivia. Importantly, no more than 20% of a participant's time was spent completely sedentary. When considering that this was the final session of the evaluation, and therefore the novelty of the system may have begun to wear off (discussed in Section 7.6), it is pleasing to note that participants generally remained physically active throughout the session. This confirms iFitQuest as not only a method to encourage MVPA, but also prevent sedentary behaviour. For those children not capable of reaching the higher intensity levels, iFitQuest represents a viable method to promote physical activity and avoid sedentary behaviour. Additionally, during the final session, points earned were not added to the evaluation totals of the participants. This was due to the low attendance on the day of the class (as some participants had already left the school to go on holiday). As a result, observations confirmed that some participants put in less effort during this final session. With this in mind, the data above appears even more positive. Further studies are required to establish whether in fact a 'standard' session would facilitate a greater quantity of higher intensity physical activity. In Chapter Nine, increased use of accelerometer equipment during future exergame evaluations is suggested and discussed.

By adding the ActiGraph accelerometer as an additional data gathering method, it was also possible to compare the accuracy of the mph estimation method used in previous evaluations. Comparing the results of the estimation method for the final session with the well validated accelerometer data allows for conclusions to be drawn on the suitability of the estimation technique.

The estimation method cannot account for completely sedentary behaviour due to the fact that participants always made at least some effort to move during a mini-game. As such, at its lowest the average speed was still in the light intensity threshold. As the percentage of time a participant spends sedentary cannot be measured, percentages are calculated by categorising mini-game average speeds into light, moderate and vigorous physical activity. As the accelerometer also measures sedentary time, and accounts for all movement done by the participant within a session, including that done outwith the mini-games, it was predicted that the two methods would not be closely linked, but accurate enough to provide a general estimate.

As only 8 of the participants had valid accelerometer data, the sample size is too small to conduct a valid Pearson's Correlation. However, through an anecdotal assessment, it is possible to establish that the likely correlation between the two variables is low. Table 7.7 shows the MVPA for each participant using both forms of measurement. This table shows the percentage of time each participant spent in MVPA as was calculated using both the accelerometer and mph estimation method. Note, the accelerometer data is rounded to the nearest whole percentage for continuity.

Table 7.7: Comparison of MVPA data from both estimation and accelerometer methods.

	mph Estimation %	**Accelerometer %**
David	29	35
John	75	67
Olivia	13	16
Alice	29	16
Ben	69	19
Hannah	36	38
Mia	8	28
Anna	75	16

Some participants, such as David, John, Olivia, and Hannah, had similar results for both forms of measurement, with Alice having roughly equivalent measurements. However, Ben and Anna performed considerably less MVPA, as measured by the accelerometers, in comparison to their estimation data. Researcher observations as well as post-evaluation interviews confirmed that these two participants were generally unenthusiastic during the final session. Thus, the MVPA as was established by the accelerometers is more consistent with what would be predicted. This highlights a potential flaw within the estimation method. A participant can exercise vigorously within a small number of mini-games, yet remain sedentary or in light intensity PA for the rest of the session outwith mini-games, causing their estimation of MVPA to be far higher than their actual MVPA. On the contrary, Mia showed the opposite trend. Despite the estimation method showing only 8% MVPA, she actually achieved 28%. Mia was an enthusiastic participant, often running across the playground to play with friends, compare scores, and talk with the researchers. This additional activity is not accounted for within the estimation method.

To summarise, the estimation method provided an acceptable and accurate overview of the physical activity intensities for the majority of participants. It provides a clear picture of the way participants behave within the mini-games, as well as describing how different mini-games facilitate different intensities of PA. However, as is shown above, certain participants were not accurately described due to their behaviour outwith mini-games. Thus, the estimation method, while a useful and convenient approach, should be augmented with additional data sources to provide the most accurate overview. For these evaluations of iFitQuest, it provides a useful insight into physical activity intensity; however, future evaluations should consider more prevalent use of accelerometers, as is discussed within Chapter Nine.

7.5 Motivation

Participants were asked to quantify how motivated they felt whilst playing iFitQuest. The participants quantified their motivation as 'high', with a median score of 7.75, a mode of 8.0 / 10.0, and a mean score of 7.21 (sd = 2.25, range = $3-10$). As this was measured at the end of the evaluation, at which point participants may have begun losing motivation, this represents a positive outcome for the evaluation. When asked to explain their motivation score, two of the participants that gave a score of 5 stated that it was dependent on their mood. Hannah said, "sometimes I wanted to play, sometimes I just did not". Abigail, the lowest scoring participant, gave a score of 3 due to the fact that she felt the evaluation was "boring and long and too tiring". Of those that gave higher scores, the game being fun, as well as external factors such as a desire to get more fit, were both commonly mentioned as contributing towards motivation.

Participants were asked to quantitatively rate a number of iFitQuest elements based on how motivating they found them. However, some members of the class were unable to properly complete this task due to its complexity. Instead, participants were asked to rate each game element using a binary 'yes' or 'no', where 'yes' corresponded to an element providing at least some motivation, and 'no' none at all. The frequency data is presented in Table 7.8.

While this table lacks the detail provided by quantitative scoring (some participants gave many of the elements a 'yes', so it is difficult to discern what elements were the *most* motivating), it highlights once again the diversity in what participants find motivating about iFitQuest.

It is pleasing to note that a desire to exercise and increase fitness was one of the most motivating elements. Interestingly, many participants stated they were motivated to earn points without the desire to come top of the class leaderboard. Instead, participants appeared to favour direct competition with their peers, as well

Table 7.8: Most motivating aspects of iFitQuest.

Aspect	No	Yes
Trying to improve Fitness	3	9
Trying to earn more points than the rest of the class (leaderboard)	9	3
Trying so as to beat a friends score	4	8
Trying to win at the mini-games	5	7
Trying through enjoyment of the mini-games	7	5
Trying to improve mini-game scores	5	7
Trying to earn maximum points	3	9
Trying to get praise from the teacher	6	6
Trying to beat self-set points goals	4	8

as beating self-set points totals. The motivation of specific participants is discussed in greater depth within the case study analysis (Section 7.8), in order to better explain how and why these elements proved motivating.

7.6 Novelty Effect

The related work discussed in Chapter Three highlighted the reoccurring issue of novelty effects within exergames. However, the previous evaluation found no such effect over the course of a four session evaluation. Thus, would such an effect be present within iFitQuest, when evaluated over a more prolonged period of time?

As with the previous evaluation, it is not a simple task to identify a novelty effect within iFitQuest. When analysing the data from the previous evaluation, distance was considered as one aspect of the investigation (as was effectively used within [115, 163]). However, in this analysis, it was not possible to consider distance in the same way. In the previous evaluation there was a rigid time-tabled slot for playing iFitQuest, meaning that sessions were undertaken at the same time and generally lasting the same length. However, due to the more flexible nature of this evaluation, sessions were more varied in length. With some sessions twice as long as others, it would not be valid to look at session to session distances and draw any conclusions on novelty, even if the data was normalised by session length. Additionally, increasing the number of sessions resulted in a lower percentage of participants having complete data sets (only two participants attended all sessions).

However, the intensity at which participants exercised remained valid despite the flexible nature of the study. While one could argue that in longer sessions, one may expect to see people tire and thus exercise more at a lower intensity, the length of the sessions were designed based on the advice of the expert P.E. teacher, such that participants could feasibly exercise at a higher intensity throughout. Observational data confirmed that in very few instances a participant tired sufficiently across a session to the extent that they had to alter their in-game habits.

In addition to an analysis of physical activity, player opinion, observations, interviews and accelerometer data was used to draw conclusions on the presence of a novelty effect.

7.6.1 Exercise Intensity

Using the same method outlined within the previous chapter, the average speed at which participants played their mini-games was used to infer the intensity at which they were performing physical activity during each mini-game. The amount of time spent in MVPA was then calculated by looking at the averages across all mini-games in a session. A decrease in the percentage of time spent playing games at a MVPA intensity could be one indication of a novelty effect.

Figure 7.1 shows the percentage of time spent in MVPA for each participant across the duration of the evaluation. The bold black line shows the average MVPA for each session.

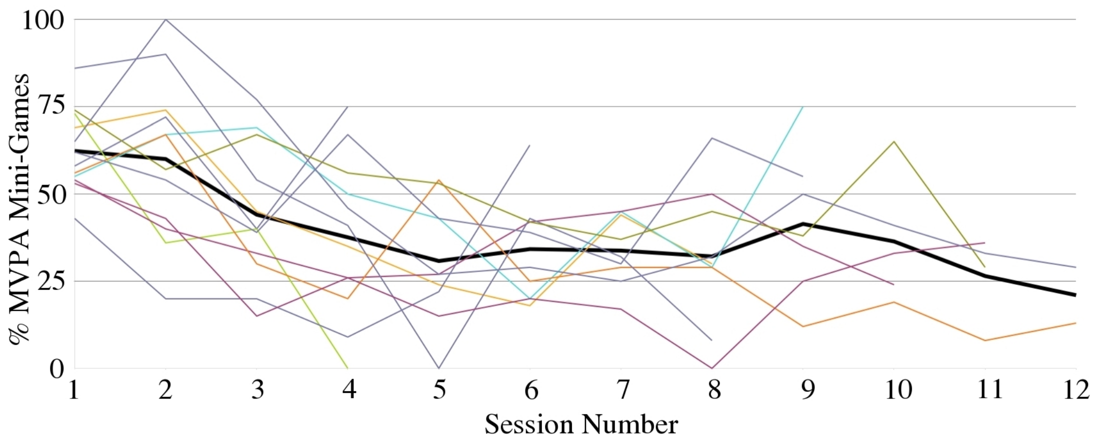

Figure 7.1: Graph showing how the participants' MVPA % changed by session.

As can be seen from Figure 7.1, there is a general decline in MVPA between participants 1st and 5th sessions, after which time the average generally plateaus and remains fairly consistent until the final session. As there was not a noticeable decline in the number of mini-games being played, this highlights that across the duration of the evaluation, participants were generally spending more time performing light intensity physical activity rather than at a MVPA level.

Alone, this does not necessarily suggest a novelty effect. The trends in Figure 7.1 suggest a downturn in MVPA from the very first session, a contrast to what was seen in the prior evaluation. This trend then plateaued where one may expect a continual decrease. The data may therefore be a result of changes to mini-game selection habits rather than a lack of motivation for iFitQuest. Regardless, this represents a problem with iFitQuest, as one would hope an exergame maintained or ideally increased the proportion of time participants were working at a higher intensity. Looking at the accelerometer data presented in Section 7.4, even during the final session of the evaluation participants were achieving MVPA, in addition to avoiding sedentary behaviour (instead spending time in light intensity exercise). Thus, even though a general downturn may have been observed, participants had not lost an interest in the game to the extent that they were no longer undertaking *any* physical activity. In playing iFitQuest, rather than alternative sedentary classroom activities, participants continued to have the benefit of physical activity across the entire duration of the evaluation.

7.6.2 Player Opinion

While none of the participants involved with the evaluation chose to opt out before the end of the study, some of the participants exhibited behaviour that would suggest the novelty of the system was beginning to wear off.

4 of the 12 participants (33.3%) stated that they would not like to use iFitQuest again. Nick stated that he "did not like it", while Ben stated, "it was boring". Abigail said that she "got bored playing the same games all the time". However, the remaining 8 participants stated that they would like to continue playing the game. David said that he wished the game was available for purchase so he could get his dad to buy it, while Alice's only complaint was that there was not more time to play the game, and the sessions did not last longer. Additionally, the previously discussed motivation scores given by the participants in the post-evaluation questionnaire had a median score of 7.75, a mode of 8.0 / 10.0, and a mean value of 7.21, representing a high level of motivation given the stage in the evaluation process.

Observationally, both researchers, and the full-time learning assistant, began to notice the general effort of the class decreasing. Some participants became less enthusiastic towards the system in the latter part of the study (approximately week 5), while on two occasions a participant asked if they could miss a session as they wanted to participate in another school activity. Anecdotally both the learning assistant and classroom teacher confirmed that this behaviour was consistent with final year school pupils nearing the end of the school year, and that observed changes in enthusiasm for iFitQuest was consistent with the curriculum as a whole. These observations would however suggest that, at least for some, a novelty effects was present, while not confirming whether this was down to the game itself or external factors.

7.6.3 Summary

While the general consensus for iFitQuest remained positive, it appears that 7 weeks may be around the limit for an iFitQuest evaluation. Physical activity data shows that during the final session, participants were getting exercise at an MVPA level as well as avoiding sedentary behaviour. However, the cross-session data shows that the proportion of MVPA was gradually decreasing, and then plateauing. When the observational data is added to this, it appears that some form of novelty effect was likely present. Based on these sources of data, had the evaluation continued to run it would be hypothesised that MVPA would continue to decline, while participants would become less enthusiastic and motivated.

As iFitQuest is exploratory in nature, it was not expected that it would be an optimal exergame experience. While it is disappointing to note that a novelty effect was beginning to show, it is none the less positive to note that the participants continued to exercise whilst playing the game. In contrast to Fish‘n'Steps, where participants completely lost interest (after a comparable period of time) [115], participants were in general still enthusiastic to play the game.

Within Chapter Eight data from both principal evaluations is used for a cross-evaluation discussion on the novelty effect.

7.7 Participant Changes

As an additional measure of the success of iFitQuest, it is important to consider the impact it had on the participants. As this evaluation represented the most prolonged use of the system, it is of interest to investigate whether any changes could be observed in the participants' attitude or fitness levels.

Table 7.9 shows the pre- and post-evaluation scores for each of the participants.

Note, one participant was absent on the day of the post-evaluation Bleep Test, therefore, their data is excluded for that aspect of the investigation.

Name	Self Reported Fitness		Enjoy Exercise		Enjoy P.E.		Enjoy Exergame		Self-Efficacy		Bleep Test	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Abigail	9	8	8	7.5	6	6	7	8	2.625	2.5	2.8	3.3
Holly	7	7	8	8	1	9	9	9	3.25	3.125	2.2	1.5
Ben	5	5	10	8	8	10	8	10	3.5	2.875	2.7	1.5
Anna	6	8	6	7	10	8	2	3	3.375	1.75	3.1	n/a
Nick	8	5	10	5	10	10	10	6	3.375	2.125	5.2	1.5
David	8	9	10	10	10	10	1	10	3.5	3.5	5.2	5.6
Alice	6	8	9	8	7	7	10	5	3.5	2.875	2.4	2.3
Olivia	7	8	6	5	2	2	6	10	2.0	2.0	2.7	2.2
John	7	7	6	3	8	10	4	4	3.5	3.125	4.6	5.6
Hannah	5	7	5	5	10	7	3	8	2.5	2.875	2.7	2.5
Jennifer	9	7	7	4	10	4.5	9	8	2.0	2.5	2.2	2.3
Mia	6	7	9	6	8	4	10	9	2.75	3.0	2.2	2.6

Table 7.9: Pre- and Post-evaluation scores for each participant.

Outlined in Chapter Six, Section 6.1, low powered statistical tests mean that any pre- and post-comparison done statistically must be interpreted with caution. Therefore, as well as conducting statistical tests, frequency data is considered for each of the 6 comparisons.

For each of the pre- and post-evaluation questionnaire categories, a Wilcoxon Signed-Rank tests (2-tailed) was conducted. For the pre- and post-evaluation self-efficacy scores and Bleep Test, a paired samples t-test was used.

1. There was no significant difference between pre- and post-evaluation scores for self-reported fitness, Z = -0.543, p = 0.707.

2. There was a significant difference between pre- and post-evaluation scores for enjoyment of exercise, Z = -2.320, $p < 0.05$. The effect size is large (r = 0.67). These results suggest that post-evaluation, there was a decrease in enjoyment towards physical activity.

3. There was no significant difference between pre- and post-evaluation scores for enjoyment of P.E., Z = -0.511, p = 0.703.

4. There was no significant difference between pre- and post-evaluation scores for enjoyment of exergames, Z = -0.770, $p = 0.492$.

5. There was no significant difference between pre- and post-evaluation scores for self-efficacy, $t(11)$ = -1.633, $p = 0.131$.

6. There was no significant difference between pre- and post-evaluation scores for the Bleep Test, $t(10) = 0.952$, $p = 0.363$.

For self-reported fitness, half of the class (6 participants) scored their fitness higher post-evaluation; 3 scored their fitness the same, while 3 scored their fitness as lower. Of those 9 participants that reported a change to their fitness, 4 of those reported only a marginal change (increase or decrease of one point). Nick and Jennifer reported considerable decreases in their fitness, while Anna, Alice, and Hannah all noted increases of 2 points on the scale. While the hope is that an exergame intervention would increase fitness, it is not surprising that some participants would decrease their opinion of their own fitness. The participants had not been trained to evaluate their own fitness, and as such they may have been misinformed on their actual fitness levels. Additionally, as iFitQuest can support participants in competition, seeing peers perform better or worse may influence opinion of fitness levels without any physiological changes.

The above Wilcoxon Signed-Rank test shows that over the course of the evaluation, participants significantly decreased their enjoyment of physical activity. Looking at the pre- and post-comparisons, 8 of the 12 participants reported a lower score post-evaluation. Of those that gave lower scores, half (4) scored their enjoyment considerably lower, with Nick decreasing his score by 5, and John, Mia and Jennifer by a value of 3. Only one participant (Anna) increased their score post-evaluation. These scores are surprising given that the participants gave high scores for their enjoyment of the evaluation, highlighting that enjoying iFitQuest is not enough to increase opinion towards physical activity. The evidence from this evaluation suggests an opposite effect, in that iFitQuest could potentially decrease enjoyment of physical activity. As this would represent a fundamental issue with iFitQuest, it is important to investigate this phenomena in greater depth, as is outlined in Chapter Nine.

Despite the decrease in enjoyment of exercising, no such change was observed with regards to P.E. While 4 participants did decrease their scores, 3 showed an increase and 5 no change. Of those that decreased their score, Hannah, Jennifer and Mia all showed a considerable decrease. Of these 3 participants, Hannah and

Mia both enjoyed the evaluation, while Jennifer gave a score of moderate enjoyment. Of those that increased their score, Holly showed a considerable increase in score (8 points), while the other improvements were more minor (2 points). In general, these scores highlight that enjoying iFitQuest is not enough to change opinion towards P.E. Although, this may be expected from an evaluation conducted outwith the P.E. class. Additionally, Jennifer and Mia, who lowered their P.E. scores, also considerably lowered their enjoyment of exercise. While iFitQuest may not be responsible for this, and the two may not be related, one would expect that a negative reaction to exercise would also result in negative reaction to P.E.

One factor that generally increased across the evaluation was the participants' attitudes towards exergames. While there was no statistical significance observed, half of the participants (6 participants) increased their scores post-evaluation, while 4 decreased their scores, and 2 kept them the same. David (increase of 9) showed a large post-evaluation change, which (as is discussed in Section 7.8.2) most likely highlights a logistical flaw with the questionnaire. Other notable increases were Hannah and Olivia, both of whom generally had good exergame experiences. The most notable decrease in enjoyment came from Alice, who decreased her score by 5. This is somewhat surprising given her high levels of enjoyment and enthusiasm towards the evaluation. However, as she was already a regular exergame player, this drop may be attributable towards an external factor. Generally increasing attitude towards exergames could be viewed as a positive outcome for an exergame evaluation.

Of particular importance to this research is self-efficacy and the way in which it influences the exergame experience. It is of interest to evaluate how the experience of playing iFitQuest can influence the exercise self-efficacy of the players. In total, 7 of the participants had lower exercise self-efficacies post evaluation, while 3 had higher and 2 were unchanged. While these scores are general to all exercise, and thus could be influenced by external factors, it is important to consider the impact of iFitQuest. Of those that lowered their scores, using a threshold of 0.5 on the scale (consistent with the previous evaluation outlined in Chapter Six), 4 participants considerably decreased their score. For two of those participants, this decrease was to be expected. Ben and Nick were the two participants for whom the evaluation was least effective. Due to a mixture of internal and external behavioural problems, both participants were prevented from playing the game (by the class teacher, not the researchers), and as such they both had negative opinions towards the game. This would very much influence their responses while completing the post-evaluation questionnaire. As both also displayed little effort while playing the game, they also performed worse than their peers, another factor that could influence self-efficacy. Alice (who is discussed in depth in Section 7.8.4) and Anna also showed lower post-evaluation scores. As both participants had limited success in the class leaderboard, and in Alice's case, some failure within mini-games, these factors could negatively impact self-efficacy. Only one participant showed an increase over the threshold, Jennifer. It is difficult to establish what may have influenced this increase, as Jennifer had only moderate success within the game (she finished middle of the leaderboard and never consistently won or lost the mini-games). The full implications of self-efficacy, and its influence over the exergame experience, are discussed in depth within Chapter Eight.

For the Bleep test, there was an equal split between those that scored higher post-evaluation and those that scored lower. While some participants showed good increases in their post-evaluation scores, for example Abigail and David, others showed considerable declines, such as Ben, Nick and Holly. On the day of the post-evaluation Bleep Test, there were considerable problems with the class. Two females became upset due to bullying, while two males were removed from the test to be disciplined. As a result, many of the participants lacked focus towards the test and exhibited less effort when performing it. This external factor influenced the performance of the class, and as such the pre- and post-evaluation scores must be interpreted with caution. It is therefore not possible to conclude whether there were any changes to fitness facilitated by iFitQuest. As was discussed in Section 7.4, iFitQuest facilitated a range of physical activity levels, and as such, through prolonged use one would expect to see some form of fitness improvement.

7.8 Case Studies

As with the previous evaluation, in order to get a deeper understanding of the in-game behaviour of the participants, a mixed-method case study approach was adopted. The case studies selected for this evaluation are representative of interesting in-game behaviours. For the case studies presented within this chapter, no formalised selection criteria was followed. All 12 participants were the focus of a case study analysis. For the sake of brevity, a subset of cases are included within this chapter. The case studies highlighted within this chapter represent the most complete and interesting cases worthy of greater discussion. Participants who missed considerable parts of the evaluation (such as Nick, John and Ben) are not included. Additionally, those participants that missed the post-evaluation interview session are not discussed in depth due to the missing data. The remaining case studies were then considered, with the following 5 selected for inclusion. While 'interesting' is a subjective criteria, the 5 case studies were chosen as they represented a range of behaviours, as well as coming from disparate backgrounds. All participants highlighted here also showed some form of prominent behaviour which fits within the discussion points of this thesis.

Note, unless otherwise stated all pre- and post-evaluation questionnaire statistics are on a scale of 1 (low) to 10 (high). This covers all self-reporting quantitative questions, such as enjoyment of exercise, enjoyment of P.E., enjoyment of iFitQuest, enjoyment of exergames, fitness levels, and motivation for playing iFitQuest. When considering the game selection habits of each participant, the final (12^{th}) session was discounted for validity, due to the novel inclusion of accelerometers and the decision that points would not be counted.

7.8.1 Case Study 1: Hannah

The first case study focuses on Hannah, a 12 year old female with a generally mixed attitude towards exercise and her own ability to perform PA. Pre-evaluation, Hannah did not participate in any sports outwith her school P.E. class. While Hannah did rate her enjoyment of P.E. as 10, she self-reported both her fitness and enjoyment of exercise as 5, the lowest in the class for both categories.

Pre-evaluation, Hannah classed herself as a 'non-gamer', stating that she played video games only on occasion. Prior to iFitQuest, Hannah had tried playing an exergame, however she did not particularly like them.

Hannah is an important case for analysis. Pre-evaluation, both the teacher and the classroom learning assistant had observed that Hannah had a particularly negative outlook on herself, regularly describing herself as "fat". Her Bleep Test score was not the lowest in the class, but pre-evaluation she could be considered one of the least fit children in the evaluation. The hope for a participant like Hannah is that through playing iFitQuest, it is possible to begin changing her negative attitude towards herself and exercising.

7.8.1.1 Evaluation Overview

Hannah enjoyed the exergame evaluation, quantifying her overall enjoyment as 9 out of 10, and stating that given the opportunity, she would like to participate in another evaluation using iFitQuest.

In terms of points performance, Hannah was the 2nd highest scoring member of the class and highest scoring female.

Through observations, it was established that Hannah generally played low intensity games, often commenting to the researchers that she did not enjoy running. She also played the game alone, not choosing to interact with her peers. She was also very private about her in-game performance, for example, refusing to share current points totals or Mystery Game PBs.

Table 7.10: Hannah's pre- and post-evaluation scores.

	Pre	**Post**
Self-reported fitness	5	7
Enjoyment of exercise	5	5
Enjoyment of P.E.	10	7
Self-efficacy	2.500	2.875
Enjoyment of exergames	3	8
Bleep Test Score	2.7	2.5

Table 7.10 shows one notable improvement, Hannah's self-reported fitness. This particular change can be corroborated with observations from the full-time classroom teaching assistant. She observed that Hannah generally seemed happier about herself, and that on a number of occasions, she had spoken more positively of her fitness and the way iFitQuest made her more active. During the post-evaluation interview, Hannah stated that she "felt a wee bit fitter", confirming the teaching assistant's observations. Hannah also showed an increase in self-efficacy, although only slight, this represents a positive outcome from the evaluation.

Conversely, Hannah showed a decrease in her enjoyment of P.E. As the evaluation was run outwith the school P.E. class, this decrease can not be directly attributed to iFitQuest. Indeed, her high enjoyment of the evaluation and more positive outlook on her own fitness may suggest that external factors influenced the decrease.

Also, Hannah showed no change in her attitude towards exercise. Despite enjoying the evaluation and having a more positive outlook on fitness and exergames, iFitQuest appears to have been unsuccessful in raising her opinion of exercise. At the end of the study, Hannah still did not participate in any physical activity outwith her P.E class.

7.8.1.2 Gameplay Patterns

In total, Hannah played the game on 10 separate occasions (11 including the accelerometer session), in the process playing a total of 179 mini-games.

Hannah is an interesting example of someone who adapted their gameplay habits over the course of the evaluation. As can be seen from Table 7.11, Hannah began by sampling a variety of games. However, by session 3 she was predominantly playing Collect the Coins. Figure 7.2 shows the percentage of time Hannah spent playing the Collect the Coins game by session.

Table 7.11: Hannah's session by session game selection habits.

	Session Number									
Mini-Game	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Escape the Wolf	3	1	2	0	1	0	1	0	0	0
Collect the Coins	6	7	10	14	12	12	14	5	15	11
Follow the Chicken	1	1	0	0	0	0	2	0	0	0
Return the Sheep	1	1	2	1	0	0	1	1	1	1
Visit the Fields	1	1	2	1	2	0	1	0	0	0
Mystery Games	5	4	5	5	5	3	6	1	5	5

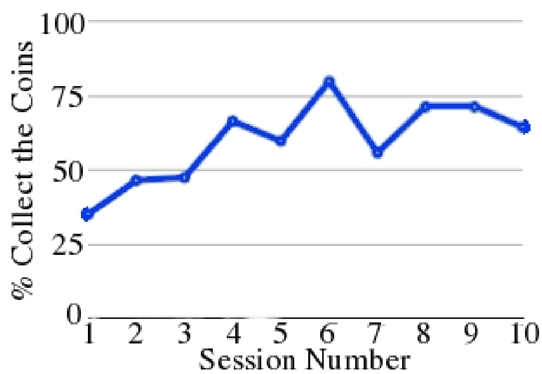

Figure 7.2: Hannah's Collect the Coins play rate by session.

When Hannah was asked to outline her strategy, she stated that she simply picked games at random. Despite this, Hannah showed a clear preference towards the Collect the Coins game, as is confirmed by Figure 7.2 and Table 7.11.

In terms of further in-game behaviour, over the course of the evaluation, Hannah only twice made a custom change to the difficulty level, in both cases making the mini-games easier for herself. The predominant reason for so few difficulty changes is that Hannah always went back to the main menu after playing a mini-game, meaning that the opportunity to override the new difficulty level was lost. In the Section 7.8.1.4, observational notes and interview data are consulted to explain the probable reasons for this behaviour.

Table 7.12: Hannah's mini-game success rates.

	Wolf	**Coin**	**Chicken**	**Sheep**	**Fields**	**Mystery**
Win	2	88	2	3	18	1
Lose	6	18	7	5	26	3
Success %	25%	83%	22%	37.5%	40%	25%

In the post-evaluation questionnaire, Hannah rated Collect the Coins as her favourite mini-game. Collect the Coins was also the mini-game she played most frequently and the game in which she had the greatest success. As Hannah had a below average self-efficacy and poor opinion of her own fitness, it is not surprising that she focussed on, and enjoyed most, the mini-game in which she had the most success.

7.8.1.3 Activity Levels

Hannah focussed predominantly on those mini-games which could be played at a lower intensity. Table 7.13 shows Hannah's accelerometer data taken from the final session.

Table 7.13: Hannah's accelerometer physical activity intensity breakdown.

Sedentary	**Light**	**Moderate**	**Vigorous**
14.8%	47.7%	13.6%	23.9%

This data was taken from a 22 minute session, showing that whilst playing iFitQuest, Hannah exercised for approximately 17 minutes, with 7.5 minutes at a moderate to vigorous intensity. Although playing iFitQuest contributed only slightly towards her daily guideline of 1 hour of MVPA, it still provided her with 17 additional minutes of physical activity during a time when she would normally have been sedentary. For a child like Hannah, who did not participate in any extra curricular physical activity, this represents a positive change.

Table 7.14 shows the breakdown of Hannah's physical activity as estimated using her in-game average speeds.

Both the accelerometer and average speed data highlight that Hannah spent the

Table 7.14: Hannah's average physical activity intensity breakdown.

Intensity	Frequency	%
Light	128	71.5%
Moderate	21	11.75%
Vigorous	21	11.75%
Flawed Data[6]	9	5%

greatest portion of her time within the game exercising at a light intensity. This is not surprising given her low fitness level and negative outlook on exercise and her own exercise ability.

7.8.1.4 Motivation

Hannah quantified her overall motivation level while playing the game as 5, listing the following as the most motivating elements of the game:

1. Trying hard to come top of the leaderboard.
2. Trying hard to earn more points than previous weeks.
3. Tying hard as she simply enjoyed the games she was playing.

Hannah listed 'getting praise from the teacher' and 'beating her friend's scores' as two elements of the game that provided no motivation to her.

These two lists provide interesting insight into the way Hannah chose to play the game. On one side, Hannah was motivated to come top of the leaderboard. Hannah stated that she "never usually won anything to do with sports" and that this motivated her to come top of the class. However, at the same time, she stated that she was not motivated to beat her friends' scores. This behaviour was observed on a number of occasions throughout the study. When her peers asked how many points she had earned, she would refuse to share any information, or compare her progress. During the interviews, she stated that she liked the role of the leaderboard, but found some people used it to become "too competitive" and that people could "take it too far".

Although Hannah was motivated by earning points to come top of the class leaderboard, she also utilised them with respect to goal setting and performance tracking, as highlighted by point 2 on her list of motivating factors. During the post-evaluation

[6]Due to errors in the GPS data, some log-files were unusable. When a GPS connection was lost during a mini-game, the log-files were discarded for greater validity.

interviews, Hannah stated, “I always gave myself a points target of 100. If I reached that, then I was happy with my performance”. The in-game points system was seen as a way to gauge performance. Hannah worked out what was an achievable, yet challenging, points total, and set out to achieve that every session.

Through interviews and observation, it can be concluded that the reason why Hannah always revisited the main-menu was because she wanted to constantly check her points score, both her total evaluation points and her daily session points. Hannah wanted to continually track her progress while also ensuring that she was being properly acknowledged for her efforts.

7.8.1.5 Discussion

Hannah provides an interesting case study for a number of reasons. First of all, she is someone who came into the evaluation with a low opinion of exercise, her own fitness, and her body image. Given her background, it was of interest to evaluate how effectively iFitQuest could facilitate physical activity while providing enjoyment and motivation.

Hannah’s in-game behaviour, as well as post-evaluation responses, highlight that a points system provides more than just an abstract method for comparing performance amongst peers. Hannah used the flexibility of the system as a way to set herself goals and track her performance. Although Hannah rated the leaderboard as important to her motivation, and she performed well in earning points, she had little interest in head to head competition, a possible reflection of her low confidence and self-efficacy.

Hannah’s low self-efficacy played an important role in her exergame experience. The level at which she set herself a points goal, achievable and unchanging, is consistent with someone who has a lower self-efficacy [14, 15]. The fact that she was unwilling to persevere with the mini-games in which she experienced little success is also consistent with self-efficacy theory.

Hannah serves as an example of the successful way iFitQuest was designed to act as a level playing field. Despite having a low fitness level, Hannah was capable of performing well within the game, and subsequently she finished high on the class leaderboard. Further discussion on Hannah’s experience, and the implications of self-efficacy are outlined in Chapter Eight. In particular, the way in which a better understanding of self-efficacy could potentially encourage participants like Hannah to spend greater portions of a session performing MVPA.

7.8.2 Case Study 2: David

The second case study focuses on David, an 11 year old male who, pre-evaluation, had a positive attitude towards physical activity as well as high exercise self-efficacy (3.5 on the PASS scale). Pre-evaluation, David participated in a number of sports, including football and athletics, and his high Bleep Test score (5.2 - the highest in the class pre-evaluation) was a reflection of his good fitness levels.

While David is generally not the type of person a physical activity intervention would aim to target, he still represented an important challenge for iFitQuest. Given his background in PA, David represented a test of how iFitQuest appeals to existing sports enthusiasts. Additionally, given his high levels of fitness, it was important to evaluate how iFitQuest could challenge and motivate him.

As well as this, behaviourally, David had a history of having a short attention span and general misbehaviour; thus it would be considered a success if iFitQuest kept David interested for the duration of the evaluation. This was something his teacher doubted would be possible. Finally, despite David's positive outlook on exercise, he expressed a strong dislike to exergames pre-evaluation (0 despite being asked to rank the game from 1 to 10), providing one more potential challenge for iFitQuest.

7.8.2.1 Evaluation Overview

At a general level, David enjoyed the exergame experience, quantifying his enjoyment as 9, and stating that given the opportunity, he would like to participate in another intervention using iFitQuest.

In terms of points performance, David was the highest scoring participant in the class, meaning that he came top of the class leaderboard.

Through observations, it was established that David was a determined and highly competitive individual. In each session he tried hard to accrue as many points as possible. Over the course of the evaluation, David adapted his tactics and play style in order to maximise his points earning potential.

Table 7.15 highlights Davids pre- and post-evaluation scores for the key evaluation measurements:

Post-evaluation, David showed no change in his enjoyment of exercise, enjoyment of P.E., or his exercise self-efficacy . As pre-evaluation David had high scores in each of these respects, it is positive to note that iFitQuest did not lower these scores.

Table 7.15: David's pre- and post-evaluation scores.

	Pre	**Post**
Self-reported fitness	8	9
Enjoyment of exercise	10	10
Enjoyment of P.E.	10	10
Self-efficacy	3.5	3.5
Enjoyment of exergames	0	10
Bleep Test Score	5.2	5.6

David scored slightly higher on the Bleep Test post-evaluation. Although this may be due to external reasons (as mentioned, David participated in sport outwith the study), observations and PA data (Section 7.8.2.3), highlight that iFitQuest could have resulted in some small fitness gains.

David scored his enjoyment of exergames considerably higher post-evaluation, highlighting once more that he enjoyed using iFitQuest. In one respect this is a positive finding, given his more positive outlook on exergames could result in a greater chance of playing exergames again in the future. This does however highlight a potential issue with the questionnaire data. David had a particularly bad session on the day where he filled out the pre-evaluation questionnaire (children were given a trial of the prototype to play before their details were collected). David felt frustrated and embarrassed as he could not understand how to play the game, while his peers' had no problems. As a result of this, David expressed a hatred to all exergames. This highlights the often inconsistent nature of children, something that must be taken into account when examining feedback.

7.8.2.2 Gameplay Patterns

In total, David participated in 11 sessions (12 including the accelerometer session) playing a total of 213 mini-games. Table 7.16 highlights the frequency with which David chose to play each mini-game, organised by session number.

David is an another example of someone who adapted their play strategy during the evaluation, moving from sampling many games in week one to an optimised strategy for getting maximum points by the end of the evaluation. David was quick to identify his strategy when asked. He reported in the post-evaluation questionnaire that he always chose the Collect the Coins and Mystery Game. During the interview

Table 7.16: David's session by session game selection habits.

	Session Number										
Mini-Game	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Escape the Wolf	8	5	5	1	0	0	0	0	0	0	0
Collect the Coins	5	0	6	9	14	17	18	17	9	21	17
Follow the Chicken	2	0	0	0	0	0	0	0	0	0	0
Return the Sheep	0	0	0	0	0	0	0	0	0	0	0
Visit the Fields	2	0	0	0	0	1	0	1	0	1	1
Mystery Games	5	3	4	3	5	6	6	4	3	7	7

he stated that this was because these mini-games allowed him to earn the most points. He also stated that the Collect the Coins game was his favourite because, "I got much more points and it was easy". He saw this game as a simple, quick method to earn points, and as such, he devised a plan to play the game as much as he could.

In terms of further in-game behaviour, David regularly altered the difficulty of the mini-games. In total, David had 42 opportunities to make changes due to the way he chose to quickly replay games, a high number in contrast to peers. Of those changes, 23 were to increase the difficulty, 2 were to decrease the difficulty, and on 17, he made no custom change to the difficulty. Of interest, David very rarely opted to decrease the difficulty level. Looking closely at the occasions when he increased the difficulty, on 8 of the 23 he increased the difficulty, he did so despite having lost the preceding game. On the 17 occasions when David opted to leave the difficulty changes to the system, on 11 of those occasions, the difficulty was increasing by default, 4 of the occasions the difficulty was staying the same, and on the remaining 2, the difficulty was getting easier. This highlights David's confidence in his own ability; of the 42 opportunities to alter the difficulty, on only 4 of those occasions did David replay a game at an easier difficulty setting. The majority of the time David wanted to play at higher difficulty levels, often despite losing at the easier levels. This perseverance and need for challenge is consistent with his high self-efficacy levels [9, 14, 15].

In contrast to the previous case study, David had far more opportunities to custom alter the difficulty level of the mini-games. Despite having similar mini-game selection habits, David consistently opted to quickly replay games while Hannah went back to the main menu to check her points. Through interviews David stated that his target was to quickly replay games in order to maximise his opportunity to gain points. This meant that during a session David had the potential to consistently remain active, with very few breaks between mini-games.

7.8.2.3 Activity Levels

While David was one of the more active participants in the evaluation, through modifications to his gameplay style, the intensity of his physical activity gradually decreased throughout the evaluation. Observations showed that while David did occasionally take breaks between mini-games, he was capable of exercising vigorously when a mini-game was demanding of it. David put maximum effort in the Mystery Games, and often finished the sessions short of breath.

Table 7.17: David's accelerometer physical activity intensity breakdown.

Sedentary	Light	Moderate	Vigorous
15.7%	49.4%	10.1%	24.7%

However, the accelerometer data for David reveals a slightly less positive picture. As can be seen from Table 7.17, a considerable portion of David's time was spent either sedentary or in the light intensity zone (65.1%). Through observations, and noted within the evaluation field notes, it was possible to conclude that this was because David made considerably less effort during the accelerometer session. As no points were available, and David was heavily driven by the class leaderboard, his motivation was affected.

Through an analysis of the 213 mini-games that David played, and the average speed that David achieved for each, a clearer picture of David's effort over the course of the evaluation can be established. Table 7.18 shows the percentage of time David spent playing mini-games at each of the different physical activity intensity levels.

Table 7.18: David's average physical activity intensity breakdown.

Intensity	Frequency	%
Light	112	52.6%
Moderate	23	10.8%
Vigorous	68	31.9%
Flawed Data	10	4.7%

Table 7.18 shows that although David did play the majority of the mini-games at a light intensity (52.6%), he also spent a considerable proportion of his time vigorously exercising (31.9%). Despite similar mini-game selection habits, Hannah spent 11.75%

at a vigorous intensity.

This data confirms what David stated in the post-evaluation interview. Although he was capable of undertaking higher intensity PA, David was more interested in the mini-games that allowed him to more easily earn points. This represents a shortcoming with the iFitQuest system. In Chapter Nine, the merits of an adaptive system which could potentially address such issues is discussed.

7.8.2.4 Motivation

David was a highly motivated individual who was driven by success and a determination to come top of the leaderboard. David rated his overall motivation level as 10 during the post-evaluation questionnaire.

During the post-evaluation interview, David stated that he was "happy to be top of the leaderboard", and that "if I wasn't top one week, I would have tried even harder". When asked about the other players in the class, David stated that "Hannah was the most competition, but she wouldn't ever tell me her score, so it made me try harder".

David rated the following elements as the most motivating aspects of the game:

1. Trying hard to coming top of the leaderboard.
2. Trying hard to earn points.
3. Trying hard as he enjoyed the games he was playing.

Although David and Hannah commented that very similar aspects provided motivation during play, they often exhibited very contrasting behaviour. David was always very interested in the scores of his peers, in particular, Hannah who he was quick to identify as his main competition in the leaderboard. While Hannah kept her score private, and focused on her own games, David spent time each session asking other people how many points they had and comparing them to his own progress. While not his highest rated aspect, beating friends provided motivation to David.

Although David didn't mention it on his list of motivating elements, he stated during the interview that every week he "wanted to beat [his] previous week's score". This is an example of David using the flexibility of the points system to give himself goals. In contrast to Hannah, who set herself an unchanging target of 100 points per week, David set out to explicitly beat his previous week's score, always setting himself more challenging goals.

7.8.2.5 Discussion

David is an interesting focus for a case study, particularly when comparing him to the other participant most motivated by the leaderboard, Hannah. While both players had similarly good performances, and similar mini-game selection habits, there were some contrasting behaviours of interest. While Hannah focused on her own performance, David was very quick to compare himself to his peers, telling the class his own points and how he was fairing, often mocking players who had a lower score.

Also, while Hannah set herself an unmoving goal, David consistently set himself ever progressing targets. Based on the literature, this behaviour can be attributed to the self-efficacy of the participants, those with higher self-efficacy gaining motivation from a discrepancy between goals and actual performance. David's perseverance when he lost mini-games, to the extent that he was willing to increase mini-game difficulty even after a loss, is also expected behaviour from someone with a high level of self-efficacy [9, 14, 15].

As mentioned above, David is someone who used the flexibility of iFitQuest to suit his needs, in this case using the points system as a means to set goals and measure performance. While earning the most points in the class was important to David, so too was reaching his own self-set points goal, importantly, a goal that was set at an ever increasing challenge level.

From the perspective of a physical activity intervention, while David did use iFitQuest to undertake physical activity, some of which was at a MVPA intensity, he does represent someone who decreased the intensity of his physical activity due to the importance of the competition. By adapting his play style, he chose to play less intense games, which resulted in a shift from higher to lower intensities of exercise. Unlike Jack in the previous evaluation, David chose to play these games at the lowest intensity he could while still receiving points.

From a methodological perspective, David highlighted that the questionnaire data must be interpreted with caution. As a result of his poor performance in the initial session, David declared a hatred towards all exergames. David's substantial increase in opinion post-evaluation highlights the potentially inconsistent nature of children. In Chapter Eight the merits of alternative data gathering techniques are discussed.

7.8.3 Case Study 3: Holly

The third case study focuses on Holly, a 12 year old female who, pre-evaluation, had a mixed attitude towards exercise and self-image. Pre-evaluation, Holly reported a relatively high enjoyment of exercise (8) and opinion of her own fitness (7). She also had a high exercise self-efficacy (3.25 on the PASS scale) and a high enjoyment of exergames (9).

She did however report a strong dislike of P.E., giving the class a score of 1. Holly also had one of the lowest Bleep Test scores in the class, with results far below the average. Further to this, through observations and interviews with the full-time classroom assistant, it was established that Holly had a poor opinion of her body image. She regularly described herself as "fat", stating that she needed to "go on a diet to lose weight".

Holly is therefore an interesting focus for a case study. She is someone with a good attitude towards exercise, while at the same time, someone who very rarely performed physical activity, emphasised by her low starting fitness levels. While Holly had low confidence in her image, she did have a high exercise self-efficacy, making her an interesting candidate for behavioural analysis.

7.8.3.1 Evaluation Overview

Holly enjoyed participating in the exergame evaluation, quantifying her enjoyment as 8. She did however state that she would not like to play the game again. In the post-evaluation interview she stated this was because she was "a bit bored towards the end...playing the same [mini-]games over and over". Holly stated that she thought the game was "fun", she liked the fact that it "got you out of class and running about", and that she preferred it to her regular P.E. class.

Holly was generally an enthusiastic and well motivated individual, who appeared to try hard during each session. Due to her poor levels of fitness, Holly often became tired and displayed a clear decline in level of activity as sessions progressed.

Table 7.19 shows that post-evaluation, Holly showed no considerable change in self-reported fitness, enjoyment of exercise, exercise self-efficacy, or her reported enjoyment of exergames. Given that Holly had high starting scores within each of these categories, it was favourable to note that this positive outlook was maintained throughout the evaluation. Interestingly, Holly stated during the post-evaluation in-

Table 7.19: Holly's pre- and post-evaluation scores.

	Pre	Post
Self-reported fitness	7	7
Enjoyment of exercise	8	8
Enjoyment of P.E.	1	9
Self-efficacy	3.250	3.125
Enjoyment of exergames	9	9
Bleep Test Score	2.2	1.5

terview that she "felt like she had improved her fitness". She also stated, "I feel more fit than I was; it makes me want to exercise more now". This confirms what the full-time learning assistant had observed in the classroom, that "Holly seems happier. She has been telling me how much fitter she feels". Holly was also observed at the end of one session telling her friend that she "just felt so much fitter". However, contradictory to this was the decrease in Bleep Test score, which would suggest a decline in fitness level. While this highlights that a physiological improvement to fitness was unlikely, the more positive outlook on physical activity and her own fitness is a considerable success for iFitQuest.

7.8.3.2 Gameplay Patterns

In total, Holly participated in 8 sessions (9 including the accelerometer session) playing 114 mini-games.

Table 7.20: Holly's session by session game selection habits.

	Session Number							
Mini-Game	1	2	3	4	5	6	7	8
Escape the Wolf	2	1	1	4	2	4	1	5
Collect the Coins	6	7	6	6	3	8	4	6
Follow the Chicken	4	1	1	0	0	1	1	0
Return the Sheep	1	1	1	0	1	2	0	0
Visit the Fields	2	0	1	1	0	0	1	1
Mystery Games	1	3	4	4	3	5	3	5

Of interest, Table 7.20 highlights greater diversity in mini-game selection habits in contrast to the previous two case studies. While David and Hannah both spent only 12.7% and 16.2% of their time not playing either Collect the Coins or the Mystery

Games respectively, Holly spent 35.1%. While Collect the Coins was her most played mini-game, Holly also consistently chose to play the Escape the Wolf game throughout the evaluation. It is interesting to look at the in-game success rate of the three games she chose to consistently play, outlined in Table 7.21.

Table 7.21: Holly's mini-game success rates.

	Escape the Wolf	**Collect the Coins**	**Mystery Games**
Win	3	29	16
Lose	17	17	12
Success %	15%	63 %	57%

Despite having a relatively poor success rate whilst playing the Escape the Wolf game, Holly persevered with playing it. Looking across the evaluation, it took until her 4th session before Holly won at the Escape the Wolf mini-game, and in one session, she was happy to play the game 5 times despite not having a single victory. Indeed during the post-evaluation interview, Holly stated that "it didnt matter if I won or lost; it didn't make me happy or sad".

Holly had a total of 9 opportunities to custom override the difficulty level. This was predominantly due to the way in which Holly was happy to play a selection of mini-games and thus rarely hit the replay game button. Of the 9 available opportunities, Holly never made a custom change to the difficulty level of the mini-game. In 5 of these cases, she had won the preceding game (and thus was happy to replay the game at a slightly more challenging level), in 2 of the cases she had lost on the easiest difficulty (and thus happy to replay at the same difficulty), and on 2 cases she lost and was happy with a slight decrease in difficulty level. Questionnaire data proved misleading in understanding her behaviour, as Holly stated that during the evaluation she both increased and decrease the mini-game difficulty to suit her needs. This highlights another logistical issue with the questionnaire, discussed within Chapter Eight.

7.8.3.3 Activity Levels

Due to her enthusiasm and commitment, it was observed that Holly was capable of high intensity physical activity within the MVPA threshold. However, due to her lower fitness levels, she generally tired during each session, meaning that the latter portions of her play were done at a lighter intensity.

Table 7.22 highlights the distribution of Holly's physical activity intensity across

Table 7.22: Holly's average physical activity intensity breakdown.

Intensity	Frequency	%
Light	54	47.4 %
Moderate	23	20.2%
Vigorous	31	27.2%
Flawed Data	6	5.2%

the entire evaluation. As can be seen, the data clarifies observations that Holly was capable of a range of intensities, but due to fatigue, still spent a high portion of time participating in light intensity exercise (47.4%). In contrast to David and Hannah, she still spent less time at a light intensity (47.4% versus 52.6% and 71.5% respectively), despite having lower fitness levels.

7.8.3.4 Motivation

As has been mentioned, Holly had high levels of enthusiasm for iFitQuest. This is highlighted by her willingness to undertake considerable amounts of MVPA despite her low fitness levels, and her determination to replay a variety of mini-games, including those in which she had limited success.

Holly was a generally motivated individual, quantifying her motivation as 7.5. When asked to explain this, she stated, "its inbetween [sic] a bit tired and I'm fit". Although this does not directly answer the question, when she was asked to clarify the meaning, she stated that as she was not fully fit, she could not always try her hardest. In her opinion, she was often physically incapable of trying any harder. This, once again, highlights her high levels of effort, often exercising to exhaustion.

Holly was incapable of providing specific values for the elements of iFitQuest that provided her with motivation. She was however able to identify those elements which at least provided 'some' motivation and those that provided none at all. In the post-evaluation questionnaire, Holly stated that the following provided her with absolutely no motivation:

1. Trying hard to come top of the leaderboard.
2. Trying hard as she enjoyed the games she was playing.

Those elements that she stated did provide her with 'some' motivation were:

1. Trying hard to beat a friend's score.

2. Trying hard to earn points.
3. Trying hard to improve mini-game scores.
4. Trying hard to earn more points than previous weeks.
5. Trying hard to win at the mini-games.
6. Trying hard to improve fitness levels.
7. Trying hard to get praise from a teacher.

While Holly's inability to quantify motivating elements makes behavioural analysis slightly more complicated, observational data and the answers she provided in the post-evaluation questionnaire gave some insight.

During the post-evaluation interview, Holly stated that the points were important to her. She stated that she compared points with friends, and that she enjoyed it when she had more points than them. She also said that she tried to get more points than she had done in previous weeks, although unlike David and Hannah, her goal setting seemed less formal in the sense that she didn't explicitly remember her previous week's points total and attempt to match or beat it.

It can therefore be inferred that the points system played an important role in motivating Holly to play the game. She enjoyed collecting points and comparing her score with her friends. She also used the points to loosely track her performance and set herself goals. However, her in-game habits (selecting games she was not likely to win) highlights that she was not driven by points to the same extent as David or Hannah.

7.8.3.5 Discussion

Holly came into the evaluation with a good attitude towards exercise, despite having low levels of fitness and a negative opinion of her body image. iFitQuest can be viewed as successful in the sense that it facilitated physical activity for Holly, in a motivating and enjoyable context. Particularly positive was the fact that, despite lower levels of fitness, Holly spent considerable portions of her time within the MVPA intensity threshold (47.4% of mini-games).

Additionally, Holly also displayed various interesting in-game habits. Again, the importance of the points system as a source of motivation was emphasised by Holly, even for those players not concerned with the overall leaderboard. Holly used the points to informally set herself goals and targets, as well as compare and contrast her fortunes with her peers on a person to person basis.

The social side afforded by pervasive gaming was of particular importance to Holly, both in a competitive and collaborative fashion. As well as comparing her points with friends, she liked to communicate other aspects of her performance. She stated, "I wanted to tell my friends that I beat the game at level 10". She was also one of a small group of females who chose to play as a team, regularly waiting to play a mystery game so that she could play along with a friend. She stated in her post-evaluation interview that this was an important aspect of the game. Although not directly supported within the system, Holly enjoyed working collaboratively with her peers, encouraging one another and running together.

Holly is an example of someone who was happy to persevere in the face of failure. Despite losing the Escape the Wolf game consistently, it did not affect her desire to play the game, or how enjoyable she found the game to be. This type of replay behaviour, as well as perseverance, can be linked to Bandura's work on self-efficacy, and at least partially explained by her own high self-efficacy [14, 15]. Although one may expect consistent failure to negatively influence her self-efficacy [12], Bandura's work highlights that this is dependent on how Holly viewed her own performance. Thus, if mini-game success was not Holly's primary goal, nor performance measure, her own establishment of a positive performance in other respects would mean no subsequent negative influence on self-efficacy levels.

7.8.4 Case Study 4: Alice

The fourth case study focuses on Alice, an 11 year old female who, pre-evaluation, had a generally positive outlook on physical activity. While Alice stated that she enjoyed exercise (9) and her P.E. class (7), she felt less positive about her own fitness self-reporting it as 6, amongst the lowest in the class. This was clarified by her Bleep Test score, which at 2.4 was also at the lower end of the spectrum and far below the average score for her demographic. Pre-evaluation she did however have a high exercise self-efficacy (3.5 on the PASS scale) which is among the highest in the class.

Alice is an interesting focus for a case study due to her high opinion of exercise, yet low participation and fitness. Due to her good attitude, one might expect her to enjoy the evaluation and use the game to contribute towards her physical activity targets. Like Holly, Alice falls into the category of someone who does not need to undergo fundamental changes to her attitude, rather she appears to be someone who simply needs the opportunity to participate. Pre-evaluation, Alice and Holly came from very similar backgrounds. Therefore this case study serves as a contrast to Holly by highlighting the diversity in behaviour supported by iFitQuest.

7.8.4.1 Evaluation Overview

Alice very much enjoyed participating in the exergame evaluation, quantifying her enjoyment of the experience as 10, and stating that she would like to play iFitQuest again. She stated she enjoyed iFitQuest as you "got a lot of exercise and it's fun". During the post-evaluation interview, Alice stated that she "liked exercising in a new way". Alice enjoyed the fact that she was exercising, behaviour consistent with her positive outlook on exercise.

Alice performed with enthusiasm throughout the evaluation, in each session having a positive outlook and trying hard. This was reflected in her interview, when she stated that her only criticism of the experience was that the sessions were too short, and that she wanted more time to play the games. As she was less focused on the competition aspect (discussed below), she was not one of the high points scorers in the class, though this did not influence her level of enjoyment.

One interesting observation was that Alice very much enjoyed the social aspect of the game. On almost all occasions, Alice chose to play the Mystery Games with a friend, even when the Mystery Games did not necessarily match up, i.e. running with a friend playing a different Mystery Game. On a number of occasions, it was observed that Alice would choose to run with a friend, even though she was not currently playing a mini-game herself. This behaviour is discussed in greater detail below.

Table 7.23: Alice's pre- and post-evaluation scores.

	Pre	**Post**
Self-reported fitness	6	8
Enjoyment of exercise	9	8
Enjoyment of P.E.	7	7
Self-efficacy	3.500	2.875
Enjoyment of exergames	10	5
Bleep Test Score	2.4	2.3

As can be seen from Table 7.23, Alice showed no considerable change in her enjoyment of exercise or enjoyment of P.E., a satisfactory outcome given the high pre-evaluation scores. Additionally, while showing no increase in fitness level as calculated by her Bleep Test scores, Alice increased her self-reported fitness score by two points. This was confirmed in the post-evaluation interview when she stated that she "felt that she got more exercise than her normal P.E. class" and that she was "more fit having played the game".

On a less positive note, Alice showed a decrease in self-efficacy score. While her post-evaluation score was still high, this was a negative outcome for iFitQuest. Possible reasons for this decrease are outlined within Section 7.8.4.5 of this case study, once Alice's in-game behaviours have been discussed.

Also of note was the reduction in her opinion towards exergames, despite giving having a high opinion of iFitQuest. Pre-evaluation Alice stated that she played exergames 'most days', and thus this decrease in opinion could have been due to external factors. Questionnaires and interviews could not establish reasoning behind this decrease in score.

7.8.4.2 Gameplay Patterns

In total, Alice participated in 10 sessions (11 including the accelerometer session) playing a total of 171 mini-games. Table 7.24 highlights the frequency with which she played each mini-game.

Table 7.24: Alice's session by session game selection habits.

	Session Number									
Mini-Game	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Escape the Wolf	8	3	5	3	6	2	1	4	11	10
Collect the Coins	3	1	1	6	1	3	15	5	5	9
Follow the Chicken	0	1	0	2	1	2	0	0	0	0
Return the Sheep	4	0	2	2	3	0	0	0	0	0
Visit the Fields	0	1	0	0	0	2	0	0	1	0
Mystery Games	4	2	5	5	6	4	7	2	7	6

The first thing of note is the variety in Alice's mini-game selection habits. While David (87.3%) and Hannah (83.8%) spent the majority of the evaluation playing Collect the Coins or the Mystery Games, Alice spent 56.7% of her time on those mini-games. Although Alice still regularly played the Collect the Coins game, she also spent a large portion of her time playing Escape the Wolf - similar behaviour to the previous case study, Holly.

Additionally, when asked what Alice considered when deciding which game to play, she answered, “Play the one I’m not very good at”. This can explain her selection of the Escape the Wolf game in particular. In total, Alice played the game 53 times, with a success rate of 26.4%. Looking at weeks 9 and 10, when she spent a significant portion of her time playing the game, Alice experienced a success rate of only 9.1% and 30% respectively. This highlights two key things; first, Alice was not discouraged by failure. Alice actively played the mini-games she knew she was not particularly good at, and found enjoyment in the challenge of success in those mini-games. Secondly, for Alice, enjoyment and success were not closely coupled. Alice rated the Escape the Wolf game as her second favourite, behind Collect the Coins and ahead of the Mystery Games, despite her low success rate.

Both Alice and Holly had very similar mini-game selection habits and preferences. However, while Holly focussed on playing the games she enjoyed, Alice focussed on playing mini-games she knew she needed to improve at, similar behaviour to Isla in the previous evaluation.

Over the course of the 10 sessions, Alice’s desire to replay games meant that she had regular opportunity to manually alter the mini-game difficulty. From a total of 54 opportunities, Alice opted to leave the difficulty ‘as is’ on 48 occasions, increasing the difficulty on 1 occasion and decreasing it on 5. Of the 48 occasions when she made no change, 30 came after a loss and 18 after a win. Where some players decreased difficulty seeking success, and others increased it seeking challenge or opportunity for more points, Alice was satisfied to follow the natural flow of the game. Alice was unable to articulate within the questionnaires and interview the logic behind this.

7.8.4.3 Activity Levels

Alice was one of the more active players in the class, reflected in her willingness to play the generally high intensity Escape the Wolf game. As has already been stated, Alice also showed a willingness to exercise outwith mini-games, running with friends even when not playing a mini-game herself.

Alice’s accelerometer data shows a different picture. The majority (83.8%) of her time during the final session was spent either sedentary or in light activity. However, through interview, as well observations, it was established that Alice was not feeling well on the day of the evaluation, which may explain her lower activity levels during the accelerometer trial.

Table 7.25: Alice's accelerometer physical activity intensity breakdown.

Sedentary	Light	Moderate	Vigorous
20.0%	63.8%	5%	11.3%

The estimation of physical activity intensity through mini-game average speed shows a picture more aligned with the researcher observation. Table 7.26 shows her overall evaluation breakdown.

Table 7.26: Alice's average physical activity intensity breakdown.

Intensity	Frequency	%
Light	75	43.9%
Moderate	29	16.9%
Vigorous	58	33.9%
Flawed Data	9	5.3%

As can be seen from Table 7.26, Alice spent a high portion of her time vigorously exercising (33.9%). Once more, this case shows the way in which iFitQuest can facilitate MVPA, especially in those with a low starting fitness like Alice.

7.8.4.4 Motivation

Alice was highly motivated when playing iFitQuest; however, unlike the previous case studies, her motivation did not come from ego-centric factors such as the leaderboard and competing with friends. Instead, Alice was motivated by a desire to overcome the mini-games and her enjoyment of the game. When she quantified her motivation as 10 out of 10, her explanation was simply because the games were fun.

When asked which factors did and did not provide her with motivation, the answers provided reflect strongly the behaviour observed during the study. Alice rated 4 things as joint top in terms of providing the most motivation:

1. Trying hard to earn points.
2. Trying hard to improving mini-game scores (i.e. earning new personal bests).
3. Trying hard to earn more points than previous weeks.

4. Trying hard to improve her own fitness.

Numbers 2 and 4 on the above list closely reflect what was seen in Alice's in-game behaviour. She chose to play mini-games she was not good at in order to improve on her performance and fitness ; she stated,"[I chose to] play the one I'm not very good at". Further to this she enjoyed the exercise aspects of the games, Alice actively set out with improving fitness as a goal. Despite the inclusion of a leaderboard and points system naturally shifting iFitQuest towards ego-based motivators, Alice remained task-centric.

Looking at the aspects which Alice stated did not provide motivation, she mentioned:

1. Trying hard to come top of the leaderboard.
2. Trying hard to beat a friend's score.
3. Trying hard to win at the mini-games.

Looking at number 1 and 3 on the list of motivating elements, Alice states that earning points and beating previous week's points totals were important to her. However, she also states that she had no interest in coming top of the leaderboard. This is an example of a *Task-Mastery* approach. Points were seen as a way to track her in-game progress, not as a way to compare her performance to other players. This task-mastery attitude is consistent with her in-game behaviour and her self-proclaimed desire to improve fitness, as well as succeed at the games she was not initially good at.

7.8.4.5 Discussion

As with Holly, Alice came into the evaluation with a low level of fitness, yet a generally positive outlook towards exercise and physical activity. iFitQuest successfully encouraged Alice into varied intensities of physical activity, within a context she found particularly enjoyable.

Alice provides a contrast to the previous case studies, in that her mini-game selection habits were generally driven by a task-mastery approach. Alice actively sought out, and found enjoyment within the games she knew she was not good at. As a result of this, Alice showed greater variety in mini-game selection habits in contrast to her peers. This behaviour is similar to Isla, discussed in Chapter Seven.

While Alice may have chosen to play mini-games she wanted to improve at, her high self-efficacy played an important role in her perseverance within those games. Despite very regularly losing the Escape the Wolf game, she continued to play it, with the goal of seeing herself improve. Bandura's work on self-efficacy can explain this high level of perseverance towards her goal, and her positive attitude in the face of failure [14, 15, 16]. However, the implications of this failure may have been influential on Alice's decreased self-efficacy. With Bandura showing that past performance is an important factor in self-efficacy establishment [12], it is to be expected that repeated failure would negatively influence one's self-efficacy. This in turn, could have a negative long term impact on Alice's exercise habits.

The decrease in Alice's self-efficacy is another contrast to the previous case studies. The impact of goal setting is further discussed within Chapter Eight. In particular, methods to utilise self-efficacy while reducing the risk of decreases is outlined.

Alice's desire to cooperatively play with her peers, even when not playing her own mini-games is another unique piece of in-game behaviour. Alice was willing to run with and motivate a friend, even when there was no personal benefit in terms of points or score. In the post-evaluation interview Alice stated "I liked having friends there to play with, but I was not bothered about beating them". This behaviour highlights the motivating nature of cooperative play. It is also of interest in contrast to the two previous case studies, David and Hannah, for whom this type of behaviour, a distraction from earning points, would be undesirable.

Finally, Alice provides an example of the loose coupling between success and enjoyment. She said during the post-evaluation interview, "It didn't matter about game outcome, I just wanted to keep playing". While Alice was motivated to improve her in-game scores, losing did not affect her enjoyment, nor her desire to replay games. While Alice did struggle with a number of the mini-games, it was positive to note that due to her background and motivations, she was willing to keep persevering. While a decrease in desire and enjoyment were not noted in this evaluation, the decrease in self-efficacy is an indicator that, had a lack of success continued, Alice's attitude may have begun to decrease.

7.8.5 Case Study 5: Mia

This fifth case study focuses on Mia, an 11 year old female. Mia came from a background of exercise, participating in a number of sports including dancing, gymnastics, trampolining and athletics. Pre-evaluation she also stated she enjoyed both exercising (9) and her P.E. class (8). Despite this, she rated her fitness levels as 6, and was the lowest scorer in the pre-evaluation Bleep Test. Mia had an ‘average’ pre-study self-efficacy (2.75 on the PASS scale).

Mia classed herself as a gamer, playing most days. She also had previous experience with exergames, stating that she very much enjoyed playing them (10) and that they were a worthwhile source of physical activity.

Mia provides an interesting focus for a case study analysis due to her extensive exercise and exergame background. Given her frequent participation in both traditional exercise and video games, it was interesting to evaluate how iFitQuest would appeal, while also supporting her lower levels of fitness.

7.8.5.1 Evaluation Overview

Mia enjoyed the exergame experience, rating her overall enjoyment as 9, and stating that she would like to play the game again. Mia specifically mentioned the fact that “it gets you exercising” as the reason she would like to play the game again, highlighting her enjoyment of the way iFitQuest supported physical activity.

Mia was highly motivated, and during each session, tried her best to accumulate points. While she did pay close attention to the leaderboard, due to regular absences from school, Mia found herself with an average overall points score.

Observation and log-file analysis highlight that Mia played a mixture of mini-games. She spent periods of each session exercising vigorously, before often tiring and becoming sedentary.

Table 7.27: Mia’s pre- and post-evaluation scores.

	Pre	**Post**
Self-reported fitness	6	7
Enjoyment of exercise	9	6
Enjoyment of P.E.	8	4
Self-efficacy	2.75	3.00
Enjoyment of exergames	10	9
Bleep Test Score	2.2	2.6

Table 7.27 shows Mia’s pre- and post-evaluation scores. As can be seen, Mia showed a notable decline in her enjoyment of P.E. and enjoyment of exercise. As Mia

enjoyed using iFitQuest, and was enthusiastic throughout the evaluation, it may be that the decrease was due to external factors.

On a more positive note, Mia performed slightly better on the post-evaluation fitness test. While this must be interpreted with caution, especially given Mia's active participation in sport outwith iFitQuest, along with her slight increase in self-reported fitness, this represents a positive change over the course of the evaluation.

7.8.5.2 Gameplay Patterns

In total, Mia participated in 6 sessions (7 including the accelerometer session) playing a total of 96 mini-games.

Table 7.28: Mia's session by session game selection habits.

	Session Number					
Mini-Game	**1**	**2**	**3**	**4**	**5**	**6**
Escape the Wolf	6	6	0	4	0	2
Collect the Coins	1	6	5	11	4	8
Follow the Chicken	1	2	2	1	0	0
Return the Sheep	0	0	0	0	0	0
Visit the Fields	1	2	3	1	1	1
Mystery Games	5	6	4	6	2	5

Table 7.28 shows that while Mia did spend a considerable amount of time playing the Collect the Coins mini-game, she also tried various other mini-games, most prominently Escape the Wolf and Visit the Fields.

When asked how she selected which mini-game to play, Mia stated "Doing the wolf game, and after that, I would walk when I was tired and do the coin game". Mia is the only known example of someone that made choices based on anticipated levels of fatigue. She chose to play the high intensity mini-games early in the session, knowing that when tired, she could still play the more flexible Collect the Coins. This point was clarified by her answers in the post-evaluation questionnaire.

Due to the varied nature of Mia's play, she had 18 opportunities to alter the default mini-game difficulty levels. Of those 18 opportunities, she took just two, choosing to increase the difficulty level on both occasions. In the post-evaluation questionnaire, Mia provided no further explanation on this in-game behaviour.

7.8.5.3 Activity Levels

As has been mentioned, Mia made a special effort to play high intensity mini-games during each session. This is reflected in her activity levels, both during the accelerometer trial and the aggregated analysis of her overall session details using the estimation method.

Table 7.29: Mia's accelerometer physical activity intensity breakdown.

Sedentary	**Light**	**Moderate**	**Vigorous**
15.6%	56.7%	13.3%	14.4%

Table 7.30: Mia's average physical activity intensity breakdown.

Intensity	**Frequency**	**%**
Light	51	43.6%
Moderate	19	16.3%
Vigorous	39	33.3%
Flawed Data	8	6.8%

Both Table 7.29 and Table 7.30 show the range at which Mia undertook physical activity while playing iFitQuest. While the results show more time spent at the lower end of the intensity spectrum, as expected given her low starting fitness, they none-the-less highlight the way in which someone can achieve MVPA when determined. The aggregated data in Table 7.30 highlights the lowest difference in percentage between light and vigorous exercise (10.3%) when compared to the previous case studies.

This data highlights the support provided by iFitQuest, allowing participants to achieve MVPA while also allowing lighter intensity physical activity when a participant becomes fatigued.

7.8.5.4 Motivation

Mia was another motivated participant who remained enthusiastic throughout the evaluation. She quantified her motivation levels as 8, stating that she sometimes found herself just too tired to exercise, hence not being able to give a 10.

As has been discussed, Mia selected games based on how tired she was, selecting high energy games at the start of the session before moving onto the low intensity games. By looking at Mia's motivations, it is possible to understand her motivation for adopting this tactical thinking.

Mia listed the following three things as providing the greatest amount of motivation:

1. Trying hard to come top of the leaderboard.

2. Trying hard to beat a friend's score.

3. Trying hard to win at the mini-games.

The above list shows someone who was heavily motivated by competition, both on a class level with the leaderboard, and on a head-to-head level with her peers. Indeed, she used the blank space in the questionnaire to specifically mention "to be better than David" as an element that provided her with motivation. On the one level Mia was highly motivated by these ego attributes. However, Mia mentioned the Mystery Game, and the way she can target an improvement in her PB, as heavily motivating and something which made the Mystery Games her favourite mini-game. Mia got motivation from both ego-based and mastery-based aspects of iFitQuest.

7.8.5.5 Discussion

Mia came into the evaluation with a positive outlook on exercise, frequently participating in organised sport despite her low level of fitness. For Mia, iFitQuest was well suited, supporting her in achieving MVPA and avoiding sedentary behaviour.

Mia also showed some interesting in-game habits. Rather than choosing mini-games simply to maximise points, Mia chose to play the mini-games which would allow her to earn points while also maximising energy expenditure. Despite having higher points earning potential in Collect the Coins, she wanted to play high intensity games which would allow her to earn points, while also providing greater in-game challenge. This is contrasting behaviour to David, who driven by points, wanted to maximise his points while minimising the physical effort required. Mia provides another example of a unique motivation which heavily influenced in-game behaviour.

Mia is another participant who exhibited goal setting behaviour, this time within the context of the Mystery Game. She stated it was her favourite game as she had a clear goal and a way to measure success and improvement. Mia is an interesting case in that she was motivated by both task-, and ego-based factors. She wanted to improve at the Mystery Games, while also beating David at his points score. This highlights how motivation from two contrasting elements can be combined to provide an overall motivating experience.

7.8.6 Additional Case Studies

Within this section, 5 case studies have been presented and discussed. As a reminder, for the sake of brevity, the remaining case study analysis which took place on the remaining participants is not included in this document. However, example of behaviour from all cases is considered during the discussions, particularly within Chapter Eight.

7.9 Discussion

Once again, the primary discussion for this evaluation is reserved for Chapter Eight, at which point the results of both principal evaluations are discussed together. In this section, preliminary discussion with regards to the research questions outlined within Section 7.1 occurs. In particular, this section covers key measures of an exergame success such as whether it is enjoyable to play and physically demanding. Going deeper, preliminary discussion on intervention context as well as the logistical lessons learned from this evaluation are outlined. Although the impact of self-efficacy on the experience of the participants is touched upon, this discussion is saved almost exclusively for Chapter Eight.

7.9.1 Is iFitQuest enjoyable to play?

The evidence presented within this chapter suggests that iFitQuest was enjoyable to play. The participants' median and mean enjoyment scores were moderately high, 6.5 and 6.83 (sd = 2.1) respectively. Additionally, the majority of participants wanted to continue playing the game within the context of a similar evaluation. Hannah felt that the game was "fun and exciting", while Alice appreciated the fact that "you got lots of exercise".

While Collect the Coins and the Mystery Games were again the most popular, there was a variety in the opinion of the players that highlighted the need for diversity. For many of the participants motivated by points, Collect the Coins was seen as the easiest and most effective method to add to their totals. Therefore, changes in future iterations to balance this shortcoming may result in a more even distribution of mini-game selection habits and preferences.

7.9.2 Is iFitQuest physically demanding

Once again, the results of this evaluation highlight the way iFitQuest can effectively facilitate physical activity. The results presented within Section 7.4 highlight that iFitQuest facilitated a range of physical activity intensities, right through to the final session of the evaluation. Additionally, through the use of tri-axial accelerometers, it was possible to establish that iFitQuest not only promotes MVPA, but also provides a valid method to minimise sedentary behaviour. Accelerometer data shows that even amongst those that do not, or can not, reach the more intense levels of physical activity, iFitQuest provides a source of light intensity physical activity with very little time spent sedentary.

While the Bleep Test showed no quantifiable improvement in the fitness levels of the participants, many self-reported that they were physically active whilst playing the game, as well as self-reporting increased fitness post-evaluation. Holly stated, "I feel more fit than I was; it makes me want to exercise more now", while Alice "felt that she got more exercise than her normal P.E. class".

While it is not possible to conclude that there were discernible improvements to the fitness levels of the participants, through the analysis of the in-game log-files, as well as the data provided by the accelerometer, it is possible to conclude that not only is iFitQuest physically demanding, it also promotes physical activity at all levels of intensity. Therefore, it not only reduces sedentary class time, but also contributes towards the physical activity targets of the participants. Also interesting is the way in which some of the lower fitness participants, such as Mia (Section 7.8.5) and Alice (Section 7.8.4), were amongst those that achieved the greatest portion of MVPA.

7.9.3 Is there a novelty effect within the iFitQuest system?

Through an analysis of physical activity intensity, coupled with researcher observations and player opinion, it is possible to conclude that some form of novelty effect was likely present, becoming more prevalent as the study came to a conclusion.

The results suggest that the length of this evaluation, 7 weeks, is likely around the ideal length for an iFitQuest intervention, with any more time most probably resulting in more participants losing interest. It was positive to note that even on the final day of the evaluation, iFitQuest continued to facilitate physical activity and prevent sedentary behaviour. A more prolonged evaluation is required to see how player opinion continues to change beyond the 7th week of the evaluation. It is worth remembering that within traditional P.E. classes, blocks of activities are generally rotated on a 6- to 8-week period, as children will generally begin losing interest around this time. As such, these results suggest that iFitQuest likely suffers no worse a novelty effect than what would be expected from a traditional P.E. activity.

7.9.4 What is there to learn about the exergame experience through prolonged play?

Is this chapter an abundance of evidence has been presented to support the fact that the exergame experience varies with time. This validates earlier assertions that exergames must be evaluated through prolonged studies. Prolonged use of a system not only allows for conclusions on the potential benefits of an exergame, but also provides a more ecologically valid picture of the participants' experience.

Within this evaluation, there were numerous examples of behavioural change. After the initial few sessions, participants became more comfortable with the system and began to assert more control over their experience. Take for example David, after trialling many mini-games, he settled into a rhythm of playing the Collect the Coins game as a means to maximise his points output. The way in which Alice found and replayed games she was not good at would also have been lost had there not been a prolonged nature to these evaluations. In-game behaviour such as goal setting as exhibited by David, Hannah, and Mia, as well as changes in attitude, for example in David, would too have been lost.

Over the course of the evaluation, changes in game selection habits, motivation, enjoyment and goal setting behaviour were all observed and discussed within the case studies. Importantly, much of this behaviour can be explained with an analysis through the lens of Bandura's work on self-efficacy. The primary discussion of self-efficacy is presented within Chapter Eight. This allows for examples across the two evaluations to be combined, leading to stronger validity on the conclusions. In the next chapter, the following questions will be answered with regards to self-efficacy:

1. How does the self-efficacy of the participant affect their mini-game selection habits?
2. How does the self-efficacy of the participant influence replay or avoid behaviour?
3. How does the self-efficacy of the participant influence their difficulty level setting?

4. How does the self-efficacy of the participant affect their goal setting?

5. How does the self-efficacy of the participant affect their goal commitment?

6. How does the self-efficacy of the participant affect their reaction to success or failure?

7.9.5 What is there to learn about the context of the evaluation?

Throughout the development process, children at the upper end of the adolescent age range were utilised as part of the user-centred design approach. Additionally, a high school context was used for all prototype evaluations. Therefore the change in context for this evaluation represented a potential challenge for the system. In particular, two primary questions arose: *a*) how would a younger demographic feel towards the game? and *b*) how would iFitQuest fit within this new context?

In answer to point a), the enjoyment data presented above highlights the high level of appeal provided by iFitQuest. The children were motivated to play the game, achieving positive levels of physical activity while doing so. While the novelty effect analysis highlighted that an effect may have been present towards the end of the evaluation, it is not possible to conclude that this was due to the younger demographic, with the more likely reason the increased duration of the evaluation.

Based on this, it is also possible to conclude that iFitQuest fit well within the context of a more flexible primary school environment. While a primary school provides a more flexible context, many of the same ideals remain. For example, the game must be pick up and play to allow the game to be played at any point in the day. Additionally, the flexible design approach is effective for a primary school context where sessions can be more varied in length. All of these considerations had already been made for the high school context, due to the heavy time constraints placed upon a P.E. class. Thus, while initially visualised for a high school, iFitQuest fit equally well within a primary school, due to an effective user-centred design approach.

7.9.6 Methodological Evaluation Findings

Over the course of the evaluation, a number of additional logistical issues arose.

In hindsight, the use of a Bleep Test to evaluate the fitness of the participants may not have been the most accurate and valid approach. During the post-evaluation Bleep Test, it was observed that a number of participants scored considerably lower due to a general lack of motivation for performing the test, as well as external emotional stresses, including bullying. Alternative approaches to fitness measurement should be investigated by future practitioners. While the Bleep Test was a logical choice given its prevalent use within P.E. classrooms, for the aforementioned reasons the validity of the results it produced must be interpreted with caution. One potential alternative could be the *FITNESSGRAM* program, as is recommended by the American College of Sports Medicine in their guidelines for fitness testing [155] and validated through large scale studies [139]. One unique aspect of FITNESSGRAM is the way in which it uses criterion health standards, which are based on what is required to achieve health benefits. This type of test also provides a more balanced outlook (while the Bleep Test looks only at cardiovascular endurance) and is considered particularly effective when used to track improvements over time, as well as providing an overall fitness 'score'. This type of test may circumvent the validity issues seen with the Bleep Test.

Another logistical issue arose around the participants' understanding of the questionnaire. Although in general the class appeared to answer the questions consistently and accurately, and as such the data was still included within the analysis, there were occasions when inconsistent results were observed. For example, Holly stated that she on occasion increased and decreased the difficulty of the mini-games, while the log-files showed she did not. Some participants were also unable to quantify the source of their motivation. Although a binary alternative was suggested and effectively used, this meant that some detail to the data was lost. Additionally, David highlighted the heavy influence of external factors, with his negative initial session heavily influencing his overall opinion of exergames. Practitioners should also consider each context uniquely, with general school attainment and pupil performance likely influencing the level of questionnaire understanding [60]. While the data gathered was still useful and generally valid, in future iFitQuest evaluation greater consideration will be made towards the demographic using the system when designing the questionnaire.

Finally, as was highlighted in Section 7.4, while the mph estimation method provides a generally accurate overview of the levels of participant activity, for some participants, it can prove misleading. Participants who were particularly active outwith mini-games (for example Alice), and those that may be active during mini-games but primarily sedentary for a session, both receive inaccurate readings from the mph estimation method. The tri-axial accelerometers adopted for the final session effectively measured physical activity. However, their expense, and the added inconvenience of setting them up for each session, provide additional logistical issues. An effective approach for future evaluations would be to more frequently use accelerometers (for example, once per week) in order to augment the estimation data. This would allow for more accurate and valid trend data, without too much additional cost. The accelerometers built into the iPhone could also be considered, although their validity would first need to be established.

7.10 Summary

This chapter outlines and discusses the second prolonged iFitQuest evaluation. The goal of the evaluation was to further investigate the phenomena outlined in the previous prolonged evaluation, such as the efficacy of iFitQuest at facilitating enjoyable and motivating physical activity. Additionally, the more prolonged nature of the evaluation allowed for further insight into the exergame experience, in particular the influence of self-efficacy. Additionally, by evaluating the system within a different context, and with a younger demographic, this study represented an opportunity to evaluate the influence of the context on the exergame experience, as well as measure how well the iFitQuest design requirements were suited to a new usage scenario.

The findings outlined within this chapter highlight that not only was iFitQuest enjoyable for a younger demographic, it was also physically demanding and motivating. The additional data gathered using accelerometers allows for a well validated conclusion to be drawn on the way iFitQuest not only facilitates MVPA, but also minimises sedentary behaviour.

Although the user-centred design approach adopted for iFitQuest was done within a high school context, and with slightly older children, the evidence from this evaluation highlights that the design requirements were equally well suited to the more flexible environment afforded by a primary school context.

Despite this, iFitQuest began to suffer from what appeared to be a novelty effect. The proportion of MVPA undertaken by participants declined and then plateaued, and particularly in the final few sessions, participant attitude and motivation appeared to decrease. It is worth noting that despite the possibility of a novelty effect, participants were still exercising and enjoying the experience through to the final session.

As well as the high-level findings with regards to enjoyment, motivation, and physical activity, this evaluation allowed for a more detailed analysis of in-game behaviour. Within this chapter, 5 case studies were presented which highlight some of the interesting and varied ways in which participants catered the iFitQuest system to suit their needs, and the way in which the background of the participant influenced their behaviour. In particular, Bandura's theory of self-efficacy was useful in understanding and explaining much of the behaviour observed.

While generalisations across the two studies must remain tentative, due to the different contexts and demographics, the primary discussion of both evaluations is presented within Chapter Eight. In the next chapter, the primary discussion occurs, using evidence from both evaluations, relating the findings back to the research questions adopted for this research.

CHAPTER 8

Discussion

In the preceding two chapters, the principal iFitQuest evaluations were presented and discussed. Designed to evaluate how effectively iFitQuest functioned as an exergame, the goal of the two evaluations was to validate the system as an exergame, evaluate the iFitQuest design requirements, understand in greater depth the exergame experience, and add weight to the discussion on the suitability of exergames for a school context.

In this chapter, results from both evaluations are combined and discussed. First, a general discussion on the success of iFitQuest is presented. Following this, individual participant successes and failures are explored. An in-depth analysis of in-game behaviour is then discussed through the lens of self-efficacy. The design requirements of iFitQuest are then presented, along with evidence on how well they were met within the final system, and how valuable they were to the success of the system. Following this, various logistical lessons learned on designing and evaluation exergames are outlined.

8.1 Was iFitQuest a Success?

At the most general level, iFitQuest was designed as an exergame for adolescent children, with the aim of encouraging and facilitating physical activity within an enjoyable and motivating context. iFitQuest was evaluated in two school-based contexts: a heavily constrained P.E. class with 14 and 15 year olds, and the more flexible primary school with 11 and 12 year olds.

Despite the disparate nature of the contexts, iFitQuest was generally well received during both evaluations, with the older children's enjoyment (median and mode = 6.0, mean = 6.30) and the younger children's mean enjoyment (median = 6.5, mode = 5.0, mean = 6.83) both moderately high. In total, 10 of the 14 older children, and 8 of the 12 younger children all stated that they would like to play iFitQuest again.

With respect to physical activity, participants generally felt they received a moderate to high workout. The older children quantified their level of exertion with a median and mode of 6.0 and a mean of 6.40, while for the younger children this was quantified with a median of 6.0, mode of 4.0 / 5.0, and mean of 6.40. However, the accelerometer data and the average speed estimation method tell a more positive story. The data highlights that iFitQuest successfully facilitated physical activity, some of which was at an intensity that contributed towards the player's daily physical activity targets (see Tables 6.9, 7.5 and 7.6). Further, iFitQuest provided a flexible environment, such that participants of all backgrounds could successfully enjoy the experience. Participants like Jack were capable of playing each mini-game at MVPA levels, while other participants, e.g. Hannah who showed equal motivation, could use the system to undertake light intensity PA. Across both studies, the data highlighted that participants of all backgrounds can receive physical activity from playing the game. For those not working at a MVPA level, they are still reducing their sedentary time. The accelerometers data showed that during a session, participants were nearly always being physically active. With prior research highlighting that exergames are generally a source of light to moderate physical activity [160], iFitQuest builds upon this by facilitating a range of physical activities, including MVPA. Particularly positive, the evaluations showed that even those with low levels of fitness were capable of undertaking MVPA, e.g. Holly, often at a greater proportion than their fitter peers.

Based on the amount of physical activity performed, it is possible to infer that iFitQuest was generally motivating for the participants. In the post-evaluation questionnaires, participants quantified their level of motivation whilst playing the game as median = 6.6, mode = 8.0, mean = 6.57 for the first evaluation and median = 7.75, mode = 8.0 / 10.0 and mean = 7.21 for the second evaluation. Of greater interest, the source of this motivation varied greatly between participants, even within the constraints of a single exergame. Participants reported a 'desire to improve fitness', 'compete with friends', 'achieve their in-game goals', and simply 'enjoyment', as all heavily influencing their in-game motivation. Despite the differing contexts and player ages, there was a similar range in motivations across both evaluations, although in the longer study, more goal setting behaviour was observed. As a platform, iFitQuest was well suited for a diverse demographic. Evidence from both evaluations showed players adopting a wide variety of motivations, goals, and mini-game selection habits.

Despite these positive conclusions, the results from the longer evaluation suggest that potentially a novelty effect was observed. Observations highlighted that at least some participants gradually became less motivated towards the end of the evaluation, with log-files showing iFitQuest having decreased effectiveness at facilitating MVPA. This decline in motivation is not surprising given such an effect has generally been observed within prolonged exergame evaluations [115, 131, 163, 204, 229]. Children generally only perform between 6- to 8-weeks of a single P.E. activity, and research has shown that the exergame novelty effect is similar to that of the novelty effect within traditional P.E. lessons [204]. It is thus not surprising that after a similar amount of time, children were potentially becoming less motivated towards iFitQuest. However, case studies showed that participants altered their gaming habits based on their goals, in turn achieving less MVPA despite no decrease in motivation. Additionally, the first prolonged evaluation actually showed participants achieving more MVPA across the duration of the evaluation. This trend is opposite to that in the longer evaluation in which MVPA declined and then plateaued. Further evaluation is therefore required in order to conclusively state whether across a prolonged evaluation, participants do indeed suffer a down turn in motivation due to a novelty effect. Within Section 8.2, the importance and influence of the school ecosystem on the success of a health behaviour intervention is discussed, emphasising the influence of external factors on the success of a system. A large scale Randomised Controlled Trial (RCT) would be required to account for these factors and conclude that iFitQuest suffered from a novelty effect. Despite the potential presence of such an effect, the post-evaluation ratings were positive for both studies. Additionally, as shown by the accelerometer data, even during the final day of the second evaluation participants performed MVPA and avoided sedentary behaviour. Later in this chapter, through the discussion of participants in-game behaviour, and the re-evaluation of the original iFitQuest design guidelines, recommendations for improving future version of the system are provided. These are then emphasised in the future work outlined in Chapter Nine, with the goal of addressing potential novelty effects.

It is also positive to note how similar both sets of results are, despite the difference in the age of the participants and contexts of the evaluation. This consistency adds weight to the conclusion that iFitQuest can function as an effective exergame. Additionally, the user-centred design process and subsequent design requirements allow iFitQuest to be well utilised within different contexts.

8.1.1 Influence on the Players

One measure of an exergame's success is the way in which it influences the players of the game. Ideally the physical activity and enjoyment derived whilst playing an exergame will result in behavioural changes in the participants. Within Chapter Three, the prevalence of novelty effects, as well as a general lack of longitudinal evaluation, highlighted that exergames in their current form are unlikely to achieve this goal. The health and fitness literature reviewed in Chapter Two highlighted that it is often difficult to achieve behavioural change within medium term evaluations, and that for valid conclusions, multi-year randomised controlled trials are required.

When statistically comparing the iFitQuest pre- and post-evaluation scores, there was no significant change detected for the majority of factors. For self-reported fitness, enjoyment of exergames and exercise self-efficacy, no statistical change was detected in either evaluation. In two respects there were observed decreases in self-reported scores, enjoyment of physical activity within the second evaluation, and enjoyment of P.E. within the first evaluation. However, as neither finding was observed in both evaluations, nor did the further qualitative evaluation provide any evidence that suggested there was a flaw in the system, these results must be interpreted with caution. Larger scale evaluations, of the type suggested in Chapter Nine, are required in order to establish whether iFitQuest does indeed negatively impact player opinion for these aspects.

These results highlight important considerations for exergame developers. It is naïve to think that exergames can easily solve what is a fundamental problem with physical activity participation. Fundamental behavioural changes often require great amounts of time and effort. Prior evaluation has highlighted the potential for exergames to facilitate physical activity and prevent sedentary behaviour. The evaluation of iFitQuest clarified this and confirmed that it could be done within an enjoyable and motivating school-based context. By playing iFitQuest, players were improving their health by working towards physical activity guidelines, as well as decreasing the amount of time they were spending sedentary.

Within Chapter Nine, future work on a cluster randomised controlled trial is discussed. An evaluation on such a scale would allow for more concrete conclusions on the long term effect iFitQuest has on its participants.

8.1.2 The Successes and Failures

It is also important to consider the efficacy of the system from the perspective of individual participants. The success stories were those who had high levels of enjoyment or motivation as well as those that expressed positive changes to attitude post-evaluation. A failure can be seen as someone who significantly lost interest in the evaluation or vocally disliked iFitQuest.

From the first evaluation, Laura and Sarah had somewhat negative experiences. Laura only participated in one session, giving excuses for her lack of participation in two other sessions (she was absent for one), while Sarah participated twice but did minimal physical activity during both of those sessions, instead choosing to socialise with friends.

From the second evaluation, there were a few participants for whom iFitQuest was not effective. Nick and Ben, who were both later excluded from the evaluation for external reasons, lost interest in playing the game. Both spent the majority of their time sedentary, sitting at the side of the play area. While slightly more active, the participants Olivia and Anna also chose to spend the majority of their time either sedentary or undertaking light intensity physical activity. Both Olivia and Anna had a negative influence on one another's physical activity, as well as on occasion influencing other members of the class (in particular Jennifer). When one or both were absent, their peers were far more enthusiastic and motivated to play iFitQuest. Importantly for Olivia and Anna, iFitQuest was still an effective source of light intensity physical activity despite the fact that neither participant undertook much MVPA. In all of the aforementioned cases, the social aspect of iFitQuest worked negatively, with participation levels often changing based on who was present during a session. This was particularly true for the children in the younger study.

The expert P.E. teacher who observed each session in the first evaluation observed that, in general, it was the same people who were unenthusiastic about traditional P.E. that were also less about iFitQuest. This was particularly true of Laura who had significant issues with P.E. participation. Likewise, with the younger children, the learning assistant observed that those who were distractible and less well behaved were those with motivation and behaviour issues in other aspects of school. This is consistent with Ben and Nick's subsequent exclusion from iFitQuest due to external behavioural issues.

Despite these particular cases, as has been reported, both evaluations were largely successful. Importantly, iFitQuest appeared to have a positive influence on specific participants. Isla reignited her passion for exercise training, while Holly consistently talked about how much fitter she felt. Hannah, who stated that she had never won anything sport related, became one of the top points earners in the game. While in general pre- and post-evaluation self-reported scores show no class wide behaviour change, these specific examples highlight the positive way an exergame can influence the players.

Interestingly, the definition of success within an exergame remains open to interpretation. The core goal of a physical activity intervention is to facilitate and promote physical activity. In this respect, iFitQuest was successful for all participants, although at varying degrees. There were also notable examples of participants that embraced the system despite having low levels of fitness (for example Mia) or low levels of exercise enjoyment (for example Hannah), as well as those that had more positive attitudes towards themselves or physical activity having played the game. Self-efficacy has been found to be a predictor for physical activity participation [58]. In this respect, the results of iFitQuest are not necessarily consistent with the theory. Some high self-efficacy participants performed lower amounts of physical activity than their lower scoring counterparts, for example David. Additionally, there were notable examples of participants with low self-efficacy who embraced the system, for example Hannah. In the first evaluation self-efficacy was a generally more accurate predictor, however there were notable exceptions such as the low scoring James, in contrast to the high scoring Emily who was one of the least enthusiastic in the class. These results are not necessarily surprising given the various factors which influenced physical activity within iFitQuest, such as the goal of the player within the game or their opinion towards the system. Prior work has shown the importance of self-efficacy in predicting the success of health behaviour change interventions [201]. Further evaluation of iFitQuest, over more prolonged periods of time, is required to assess whether the system was capable of facilitating measurable changes to the participants' behaviour, and if so whether self-efficacy was indeed an accurate predictor. As is discussed within Sections 8.4.3 and 8.4.4, self-efficacy can have important implications for exergame designers and developers, due to the way it can be used to accurately understand and interpret various aspects of in-game behaviour. However, in the case of who will enjoy and participate in an evaluation, it is important to also consider the influence of the context in which it is situated.

8.2 The School as a Context

The importance of context was emphasised in Chapter Two [46, 105, 127, 199]. The positive potential for adopting the school context for general physical activity interventions [128, 157, 179, 178, 223] as well as exergames [67, 163, 195] was also discussed.

The general success of iFitQuest can be attributed to the adoption of a school context. The system was implemented into the curriculum of both schools, in one case as an alternative to traditional P.E., and in the other as an additional opportunity for physical activity. The support and enthusiasm from teachers and learning assistants, as well as the social ecosystem of a school environment, were heavily influential on the effectiveness of iFitQuest. These findings are consistent with what Xu et al. found through their deployment of the American Horsepower Challenge, in which they discovered a number of influencing factors associated with exergames in schools, including the important role of the teacher and the importance of integration into the daily routine [229].

This social ecosystem was a contributing factor in both the successes and failures of iFitQuest. David, Jack, James and Hannah are all examples of participants who thrived under class competition, while Holly and Mia enjoyed competing one-to-one with their peers. Alice, Holly, and Mia all enjoyed playing collaboratively, using social support as an additional motivator.

However, all of the notable participants for whom iFitQuest was less successful found themselves distracted by social aspects. Ben and Nick, and Olivia and Anna, behaved very differently when apart. There were also notable examples of the complicated nature of the social situation within a school context. The post-evaluation Bleep Test was heavily affected by bullying, with two female members of the class refusing to take part as long as their 'bullies' were present, while the 'bullies' were removed mid-test to receive punishment. Hannah also stated that certain participants "took competition too far", while David gloated and taunted his peers when he had more points.

Prior work has highlighted the influence of external factors such as weather on the effectiveness of an exergame [229]. Emily from the second evaluation stated that her motivation was negatively impacted by the wet grass and cold temperature. During the first week of the evaluation, Sophie said, "I like the games, but it is too cold to play them". Likewise, on one occasion, two participants in the second evaluation required extra persuasion to play the game due to light rain. Participants often became visibly less enthusiastic on the occasions when it was raining, while warm weather and sunshine generally raised spirits. Something as uncontrollable as the weather proved influential over the exergame experience, regardless of the background of the participant, or how well designed the system was.

Although not an issue within a high school context, the more flexible nature of the primary school resulted in some additional unexpected issues. On occasion, participants were removed from other school activities in order to participate in the evaluation. For example, one of the sessions clashed with rehearsals for a school wide musical show. For participants that did not enjoy choir, iFitQuest was viewed as a welcome break. Conversely, for some, the exergame evaluation became an unwelcome distraction from other activities. This became more prevalent towards the end of the evaluation, when on occasion participants asked to end the session early or were visibly more distracted than usual. It is important to note that, although this behaviour occurred in a limited subset of the participants, those that did exhibit such behaviour were not necessarily those who showed little enthusiasm towards iFitQuest. It is important to consider the fact that, although someone might find the system both enjoyable and motivating, they may still find an alternative activity more desirable. This once again highlights the influence of the context, for both positive and negative implications.

It is important to consider the context of an exergame when evaluating its success. Based on the evidence of these evaluations, external factors such as weather, current school activities, and classroom culture all have the potential to unravel or further support an exergame evaluation irrespective of how well considered the system design and dissemination into the school has been.

The aforementioned factors are for the most part very difficult to account for when developing a game. While exergame practitioners advocate the use of social play within exergames [32, 39, 203, 229], the evidence in this study highlights that it can work both ways, especially when deploying a system into a school context in which there is a unique and often times trying social ecosystem. Social as well as external factors are thus more of a consderation when deciding on the context in which an exergame should be evaluated. What this does highlight is the need for in-situ evaluation in order to fully understand the potential success of an exergame. Lab-based trials would miss a number of important factors which can dictate the success of an intervention. Furthermore, when deciding upon the success of a system, one must look beyond the game and try to understand its place within the larger context. Such a phenomena is well understood within health and fitness interventions, where the social ecological framework must be considered, see Figure 8.1.

Such an ecosystem for school-based exergame deployment must consider not only the individual participant (their self-efficacy, background in exergames and physical activity) but also the culture of the school in which the system is being implemented,

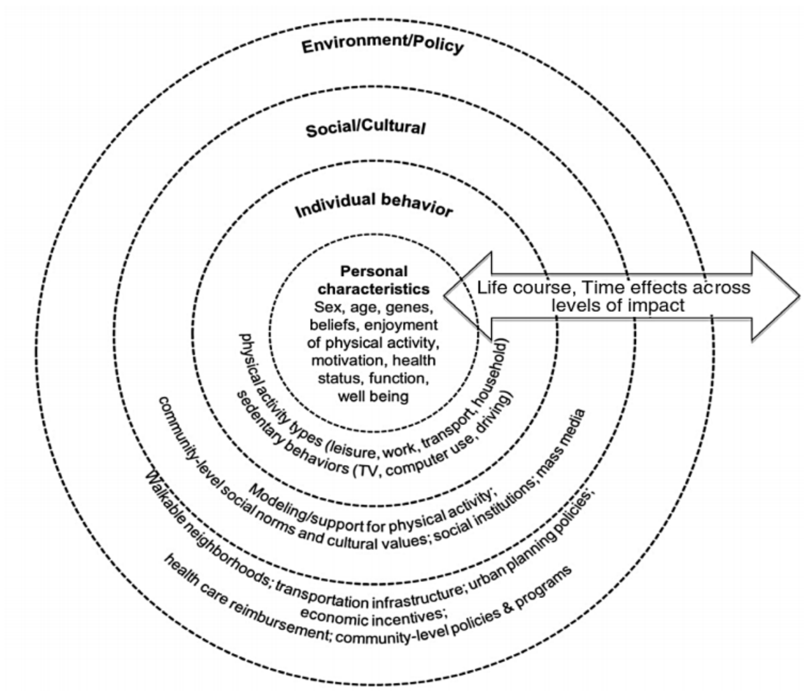

Figure 8.1: The social ecological framework presented by [102].

the support received by teachers and parents, the available facilities, and then the environment at large. Within this chapter, the important implications of self-efficacy are discussed in depth. It is, however, important to remember that various factors are at play that dictate the success of an exergame intervention. Considering these factors when deciding how to deploy and evaluate an exergame can help in establishing the success of the system.

8.3 Understanding the Exergame Experience

8.3.1 Competition and Collaboration

Exergame practitioners have already begun to evaluate the role of competition within exergames. Lin et al. [115], Poole et al. [163] and Toscos et al. [211] have all looked at how competition and raised social awareness can impact upon the effectiveness of an exergame intervention.

Within the two iFitQuest evaluations, there were a number of individuals who were motivated by the competitive aspects of the game, such as David, Jack or Hannah who looked for overall competition, or Holly and Abigail who cared more about competing directly with their friends. Due to the framing of the task, the use of a points system, as well as the novelty of researcher observations, this type of ego-based motivation is not unexpected [152].

However, there were also examples of participants, such as Isla and Alice, who drew no motivation from competition, instead showing mastery traits in trying to improve their performances. Nicholls' work showed that ego-based motivators can lead to less intrinsic motivations, which, in turn, can lead to less prolonged motivation [152]. Competition also increases the differentiated conception to evaluate oneself, which is a negative outcome for low performers and can negatively impact self-efficacy [12]. During the evaluations, there were examples of participants who exhibited negative behaviours due to competition. Ben wanted to exercise in a separate area of the playground so as to be out of sight of his peers, while Mia argued with her friends that her absences caused her lower points score, not her performance. David took pleasure in ridiculing the lower scorers in the game, while Hannah felt the need to keep her scores private to all. Additionally, David's competitive nature meant that, while his commitment to the game was strong, he changed his gameplay habits such that the amount of MVPA he undertook decreased.

As two of the most competitive participants in the latter study came from opposite ends of the self-efficacy spectrum, it is not possible to suggest that self-efficacy can predict whether someone will or will not be interested in competition within a flexible environment like iFitQuest. However, Bandura's theories of self-efficacy can predict how one would react to failure if winning the competition is their primary goal [12, 14, 15]. Competition can and has been effective within exergame interventions. However, the participant's background must be considered carefully when evaluating the suitability of a competitive exergame. Not only can these ego-based approaches, in the long-term, lead to undesirable motivations, they can also negatively affect the behaviour of the player. Especially when considering players of low ability or low self-efficacy, highlighting through competition their inadequacies is likely to cause undue stress. In the case of Daniel, the vicarious information that highlighted his low performance within the competition was likely an influential factor over his decrease in self-efficacy [12]. Exergame practitioners may therefore consider competition as one form of providing motivation, whilst simultaneously aim to encourage participants towards more mastery-based goals, such as improving performance.

There were also interesting examples of participants utilising collaboration within iFitQuest. Most notably, Alice was happy to run with her peers even when not playing mini-games herself. In both studies, participants were observed coordinating mini-games for cooperative play. The positive potential of peer support has been investigated within exercise systems [143, 158, 211]. For iFitQuest, it was interesting to see the way in which collaboration could fit within a competitive environment. Prior work has explored how competition and collaboration can interact within an exergame, although in that case both aspects were inherently supported by the system and formed the primary mechanics of play [230]. While competition was inherently facilitated within iFitQuest, some participants used the flexibility of the system to play cooperatively with their peers, often despite potential implications on the competitive aspects of the game. In iFitQuest, competition and collaboration worked effectively in tandem. Exergames that imposed one, or the other, may isolate a set of participants with implications on their experience.

Building upon this, it is also important to consider those players that wished to play the game on their own, with little interest in the multiplayer aspects of the system, be it competition or collaboration. Arteaga et al. found that while for some, multiplayer exergames can prove effective motivators, it is important to consider those that prefer single player experiences [7]. Based on the findings of these iFitQuest evaluations, providing a flexible environment that allows for single and multiplayer experiences, without forcing specific goals on the player, can allow participants to draw their own motivations and cater the experience to suit their own needs.

8.3.2 Points: More than Just Prizes

A points system was implemented into iFitQuest as a means to facilitate competition between participants. As was discussed in the preceding section, many participants utilised this by motivating themselves to come top of the class leaderboard, or by having head-to-head competition with their peers.

One additional benefit of the points system was the way participants could utilise it as part of a goal setting process. The merits of goal setting are well established as a means of providing motivation and increasing performance [116]. Despite a lack of formalised goal setting support, there were a number of examples of the points-system being used as a means to track self-set goals. Prominently, Hannah set herself an unchanging points target of 100 points per-session, while David set himself an ever increasing points target to ensure that his performance was alway improving.

While many participants ignored the points system, for others it became an effective way to validate performance and a source of in-game motivation. Although iFitQuest was designed with a variety of in-game micro- and macro-goals, the behaviour of Hannah and David and their resultant motivation for iFitQuest highlights the benefit of self-setting goals, and the way in which a points system can be used as a means to set and work towards a definitive target.

The way in which goal setting and self-efficacy interact is discussed within Section 8.4, while the benefits of a formalised goal setting approach are hypothesised within Section 8.5.12 and 8.5.13. In addition to the points system, goals in the form of personal bests, level progression, and in-game performance were all observed. Those that had the most motivating and enjoyable experiences were generally those who displayed some form of goal setting.

8.3.3 The Role of Success

Through the two principal evaluations, and to a lesser extent, the final prototype evaluation, the loose definition of success within exergames was highlighted. From a player's perspective, is success winning at the game? Is it improving fitness? Is it merely showing good effort and trying your best? When evaluating iFitQuest various definitions of success were observed; David and Hannah found success in getting the most points in the class and reaching their points goals. Meanwhile Holly and Abigail, while not interested in the overall leaderboard, found success through beating the points score of their friends. Players with a mastery focus such as Alice and Mia found success in beating their personal bests or winning at the mini-games, even if that meant losing a lot of mini-games along the way.

In the final prototype evaluation, a log-file analysis found that in exergames, success is not necessarily linked with enjoyment [121]. The two principal evaluations extend this to document the interesting ways in which people react to successes and failures. Success can provide both a source of enjoyment and a source of motivation, while for certain participants, failure can provide the most motivating aspect of all. In Section 8.4, the role of self-efficacy with respect to success is discussed.

While the overall success of iFitQuest was discussed in Section 8.1, by looking at the role of success for the individual player, more information on the overall success of the system can be abstracted. Take for example David, someone who found motivation and enjoyment from earning points, meeting his points goals, and coming top of the class leaderboard. His desire to be the highest points scorer in the class meant that the amount of MVPA he achieved while playing iFitQuest declined. For him, in-game success was inversely linked to the success of iFitQuest. Conversely, participants like Holly, who experienced little in-game success, had overall successful evaluations.

Holly challenged herself within high intensity games, getting good levels of MVPA despite her low fitness levels. These two contrasting examples highlight that in-game success may not necessarily reflect the overall success of an exergame intervention. Constructing a generally successful exergame intervention while also providing an enjoyable and motivating experience for the players requires an understanding of the individual's goals and motivations. Considering the self-efficacy of the players is one method for ensuring this balance is met.

8.4 Self-Efficacy and iFitQuest

Self-efficacy is one of the most well validated and applied psychological theories used when trying to understand an individual's motivation. Within Chapter Two, the ways it can be used to understand and influence behaviour was discussed along with its importance with respect to physical activity interventions.

The way self-efficacy can influence behaviour was hinted at within the second prototype evaluation, and formed a key aspect for consideration within the two principal evaluations. In the previous chapter the following research questions on the role of self-efficacy within an exergame were outlined:

1. How does the self-efficacy of the participant affect their mini-game selection habits?
2. How does the self-efficacy of the participant influence replay or avoid behaviour?
3. How does the self-efficacy of the participant influence their difficulty level setting?
4. How does the self-efficacy of the participant affect their goal setting?
5. How does the self-efficacy of the participant affect their goal-commitment?
6. How does the self-efficacy of the participant affect their reaction to success or failure?

Within the following subsections, each of these questions are answered using examples from both principal evaluations.

8.4.1 How does the self-efficacy of the participant affect their goal setting and commitment?

Over the course of the two principal evaluations, a number of interesting goal setting behaviours were observed. Within the second evaluation, David and Hannah were seen to use the points system to set themselves a points target for each session. In the secondary school evaluation, Jack and Ross exhibited similar behaviour, both stating that they tried to beat their points score from the previous session.

As well as the points system, there were examples of those that set themselves the goal of improving their Mystery Game personal bests (e.g. Mia), those that set themselves the goal of improving their performance on a particular mini-game (e.g. Isla and Alice), and those that set themselves a goal of reaching the highest level of a mini-game (e.g. Holly).

The adoption of goals within the context of an exergame is a favourable outcome. Locke and Latham have established within their work on *Goal Theory* the motivating benefits provided by goals. Their work concludes that challenging goals provide the most motivation [116].

Bandura's work on self-efficacy has, in many respects, considered the notion of goal setting and the way in which goal theory and self-efficacy can work in tandem. Bandura has shown that those with a high self-efficacy set themselves higher goal challenges and have a greater commitment to achieve those goals [14]. Bandura writes, "Those with a strong sense of efficacy set higher goals for themselves. Adopting further challenges creates new motivating discrepancies" [15]. A strong belief in one's performance efficacy is essential to mobilise and sustain the effort required to succeed [16]. Bandura goes on to state, "Self-Efficacy beliefs contribute to motivation in several ways; they determine the goals people set themselves, how much effort they expend, how long they persevere in the face of difficulties, and their resilience to failures" [15, p.131].

Much of the behaviour seen over the course of these two evaluations is consistent with the understanding of self-efficacy and goal setting. Participants with high self-efficacy were seen to have the strongest commitment to their goals. David, within the second evaluation, was highly determined to reach his points target during each session, to the extent that he would beg the researchers for more time when he had not reached his goal. In the first evaluation, Jack was so committed to his goals that he even tried cheating the system in order to earn more points for himself and lessen his friend's score.

Related to this is perseverance in the face of failure. As Bandura established, those with high self-efficacy have the greatest perseverance and most positive reactions to failure [15]. Again, the examples from evaluating iFitQuest are consistent with self-efficacy theory. Throughout the case studies, there were examples of those that were predominantly unaffected by failures and those that appeared to change their habits when they lost. During the first two weeks of the evaluation, Olivia sampled a number of mini-games. During this time she experienced very little success in all but the Collect the Coins game, which she subsequently adopted as her most selected game. This is similar to Hannah, who driven by a motivation to earn points, avoided the games she knew she was most likely to lose and so represented a risk. Both of these participants had low self-efficacy. Conversely, participants such as Jack, David, Alice and Holly all showed perseverance in the mini-games. In David and Jack's case, they were happy to increase the difficulty level of mini-games even when they had lost at an easier level, while Holly was happy to persevere in mini-games despite repeated failure and very little success. Participants' commitment towards their goals and their reactions to failure along the way were accurately understood by, and consistent with, the theory of self-efficacy.

One interesting piece of behaviour observed within the second evaluation was David's negative reaction to the initial trial of the game. Having failed to master the basic concept of the system, such as how to move his character, David became extremely agitated and angry. He gave up on the game, and close to tears, tried to leave the trial. This too can be explained through Bandura's work on self-efficacy. As Bandura's work has shown, when someone has a high self-efficacy, if the outcome judgement is negative and the person has limited control over their environment (as was the case when David could not master playing the game), this can lead to resentment and protest [8, 11]. When David did grasp the game, and began to have control over his environment, his high self-efficacy meant failure began to provide motivation, rather than frustration and resentment.

The way in which participants set themselves goals is also consistent with the literature. David set himself ever increasing points targets, which was to be expected from someone with a high self-efficacy. Similarly, despite repeated failures, Isla set herself challenging targets within a mini-game many participants found difficult. Bandura writes, "Adopting further challenges creates new motivating discrepancies" [15]. In contrast, despite consistently reaching her target week to week, Hannah was satisfied with her unmoving target. Rather than seek further challenge like her peers with higher self-efficacy, she was satisfied and motivated to reach this goal, even though prior performance highlighted that it should be easily achievable.

8.4.2 How does the self-efficacy of the participant affect their mini-game selection habits?

Building upon the goal setting behaviour discussed above, the self-efficacy of the participant, as well as their motivation and goals, were linked to their mini-game selection habits and in-game behaviours.

One novel aspect of iFitQuest is the way it was designed as a suite of mini-games. This was to help iFitQuest appeal to a wide demographic of players, as well as supporting variety in the intensity and style of physical activity facilitated. In addition to having the freedom to select their own mini-games, players were also frequently provided with the opportunity to set their own difficulty levels within mini-games. One questions for consideration is the way the self-efficacy of the participant influenced their game selection habits.

The source of a player's motivation was heavily influential over their mini-game selection habits. For example, David selected the Collect the Coins game as it provided him with the easiest way to quickly earn points (Section 7.8.2), while Alice and Isla (Sections 7.8.4 and 6.9.2 respectively) chose to play the games they knew they needed to improve at.

In the preceding subsection, the discussion focussed on the different ways self-efficacy manifested itself within the goal setting behaviour of the participants. As the goals of the participants and their in-game habits are closely aligned, it is natural to conclude that the players' in-game habits were also linked to their self-efficacy.

Within the second evaluation, there were a number of examples of *Replay and Avoid* behaviours. With the exception of Ben, all those participants with high starting self-efficacies showed replay characteristics. For example, David increased the difficulty despite losing mini-games, and Alice and Holly replayed mini-games despite many losses. Similar behaviour was seen from Jack and Isla in the first evaluation. In contrast, participants like Hannah, Olivia, Ben and Abigail all showed avoidance behaviour, selecting almost exclusively the Collect the Coins game which was the easiest to win, and rarely, if ever, increasing the difficulty levels of the mini-games, especially after a loss. After selecting various mini-games within the first two sessions, these participants settled into a routine of playing Collect the Coins, the game in which they had the most success. This behaviour is consistent with self-efficacy theory and confirms the observations of its influence over in-game selection habits. While Ben was an exception to the rule, he is also someone who showed a considerable decrease in self-efficacy post-evaluation, which is consistent with the low performance and troubled evaluation he had.

One might argue the prevalent selection of Collect the Coins was due to the fact it was the most enjoyable to play or had the best game mechanics. However, the interviews and observational data provide explanation as to the influence of self-efficacy over its prevalent selection. Olivia specifically stated that she selected the Collect the Coins mini-game as it was the easiest, and the one she was most likely to win. This was mirrored by both Hannah and Abigail in their post-evaluation interviews, while in the first evaluation, similar behaviour was attributed to Laura, Sophie, Sarah, and Chloe. Jack and David both chose to play the game due to its potential for earning points. One can infer from this evidence that the fact that Collect the Coins was, in general, the favourite and most played mini-game is more related to self-efficacy, and the player's motivations, than the actual game mechanics.

In-game behaviour was linked to the self-efficacy and motivation of the participants in other ways. Through a commitment to earning maximum points, Jack and David constantly re-evaluated their mini-game selection tactics, as well as regularly challenging themselves on the hardest difficulty levels. The adoption of challenging mini-games was also seen in the behaviour of Isla and Holly. The way participants decided which mini-games to play in a session, played or avoided certain mini-games, and manipulated the in-game difficulty levels was all linked to their self-efficacy levels and where they found their motivation.

8.4.3 Implications for Exergame Analysis

The implications of viewing exergames through the lens of self-efficacy extends to other practitioners looking to understand and explain, in greater depth, the behaviour of the participants in their evaluations.

For exergames that support or facilitate self-setting of goals, by understanding the self-efficacy of the participant, it is possible to explain why goals are set at particular levels. Bandura and Cervone showed that when people with high self-efficacy attain their goal, they generally go on to set higher goals for themselves [18]. Those with higher self-efficacy show discontent at matching previous performance, thus they produce a higher performance output [17]. Examples from both evaluations show that commitment towards goals, perseverance, and reactions to failure can also be explained by the self-efficacy of the participant [8, 11, 15, 16].

Future exergame practitioners who view their evaluations through the lens of self-efficacy will be able to understand the goal setting behaviour of their participants. Additionally, differing and changing motivations can be attributed towards the self-efficacy of a participant. If a player begins to avoid certain aspects of the game, or indeed the game altogether, viewing their in-game success, their motivations and goals, and their self-efficacy could explain where the problem in the system lies.

Based on the iFitQuest evaluations, and consistent with the literature, an understanding of participants' self-efficacy could help practitioners explain:

1. Goal setting behaviour - Why does a player set their goal at a particular level, and how will they react when they do or do not reach that goal?

2. Reaction to loss - When a person loses a game, how will this affect their motivation and enjoyment within the exergame?

3. Perseverance - Further to the above, when a person loses a game, how do they react towards that game? Are they willing to replay it, or do they begin to avoid it?

4. Challenge - Related to goal setting and perseverance, how much challenge does a player seek, and at what level?

5. Changes in behaviour and attitude - Over the course of an evaluation, how does the participant's behaviour and attitude towards the exergame change?

In section 8.2, the importance of context, and the implications it can have on the exergame experience were discussed. Additionally, the background of the participant, in particular their self-efficacy, can heavily influence the way they experience the exergame. For an exergame practitioner, understanding why the motivation and attitude of a participant changes over the course of an evaluation is an important consideration. Exergame practitioners should consult the self-efficacy of their participants as a means to better understand and explain the exergame experience and the general success of the system.

8.4.4 Implications for Exergame Developers

The prevalent and considerable effect of self-efficacy observed within the two principal iFitQuest studies raises questions about how understanding self-efficacy could be utilised to develop more effective exergame experiences.

Exergames that support goal setting may be improved through a consideration of self-efficacy. While goal theory highlights a positive relationship between task difficulty and effort, this only pertains to achievable tasks [118]. Additionally, Bandura has shown that unrealistically high-goals will not facilitate increases in self-efficacy or skill development [10]. As Schunk explains, "Goals beyond one's capabilities result in failure and low self-efficacy, whereas goals set too low provide no new information about one's capabilities" [181].

Within this thesis, there were numerous examples of participants who self-set goals. Consistent with the literature, these participants were also some of the most motivated. As goal setting is an effective form of motivation and performance enhancement [118, 116, 117], exergames should encourage participants to self-set goals, and then consider their self-efficacy when understanding their subsequent behaviour, or when helping them in setting subsequent performance goals. A system designed to support players in self-setting goals could provide more optimal targets through an understanding of their self-efficacy.

In addition to this, understanding the role of self-efficacy could prove influential within systems that utilise assigned rather than self-set goals. In the majority of exergames, players are given a system-set goal. For example, in the game Fish'n' Steps, rather than measuring raw step counts as the performance indicator, each participant was given a target based on measurements done during a baseline week. Performance was not measured by how many steps were taken, but how well the participant was working towards their step count goal [115]. This is an effective approach for exergames where the notion of fair play and a 'level playing field' are essential so as not do penalise those with a lower starting fitness or PA ability. As Locke and Latham have discussed, personal goals, and therefore self-efficacy, have been found to mediate performance towards assigned goals [117]. Therefore having an understanding of a participant's self-efficacy, and their own goals, is important when considering what assigned goals they should receive. If an exergame practitioner does not first consider the goals of the player when assigning their exergame goals, a misalignment would negatively affect the player's motivation.

With the influence of self-efficacy on goals clearly established, and the positive influence of goals on performance and motivation also clear, exergame developers must consider goals and the way in which effective implementation into a system could positively influence the experience of the participant. Based on the evidence of the iFitQuest evaluation, goal setting by participants naturally occurred and greatly enhanced motivation. An exergame system that could encourage and actively support the self-setting of goals is one potential way in which novelty effects could be influenced. For example, if iFitQuest provided a list of the supported goals and asked participants to set their own target, progress could then be shown to the player to enhance their motivation within a session. Although untested within this thesis, the implications of this may also stretch to systems that utilise an assigned goals approach. By first considering the self-efficacy of the participant before assigning a goal, the system will have a greater chance of setting an optimally effective target, not too high such that the player experiences demotivation and lowered self-efficacy, but not too low such that goals become too easy to achieve. Additionally, by considering the self-efficacy of the participant, and by carefully designing a goal system that could lead to increased self-efficacy, the player should experience greater intrinsic motivation towards playing the game [19]. It is hypothesised that by considering self-efficacy when designing exergames, in particular with regards to goal setting, exergames in the future could become more motivating and enjoyable and therefore less likely to suffer from novelty effects. Adding additional support for goal setting within iFitQuest is discussed within Chapter Nine.

8.4.5 Self-Efficacy: A Summary

Across both evaluations self-efficacy was a valuable tool in understanding and explaining participant behaviour. Participants with higher self-efficacy showed a greater commitment towards their goals and more resilience to in-game failures. This manifested itself into some interesting in-game behaviours, in particular mini-game selection habits and customisation of mini-game difficulty settings. With very little exception, the in-game behaviour of the participants was closely related to their starting self-efficacy levels. For those that exhibited contrasting behaviour, for example Ben's avoidance behaviour, their post-evaluation self-efficacy provides accurate insight.

The logic behind analysing iFitQuest through the lens of self-efficacy was well founded. The importance of self-efficacy with regards to physical activity interventions, as well as motivation and behaviour, was presented in depth in Chapter Two.

As Jarvis states,“There is little doubt that self-efficacy is a valid construct. It can be measured, and...it can be manipulated (as Bandura predicted) in order to improve performance.” [93]. The results of this evaluation highlight that utilising self-efficacy was an effective decision, in particular when understanding and explaining the behaviour of the participants. It is, however, important to consider alternative psychological theories, which could also be used to explain the exergame experience.

While Bandura himself believes self-efficacy to be a unified theory of behavioural motivation [9], other practitioners have looked at alternative theories. Steel and König's *Temporal Motivational Theory* aims to integrate various schools of thought into a single formula to predict an individual's motivation towards a task, with a key element being time (i.e. how pressing task completion is) [197]. Steel and König believe their results to encapsulate self-efficacy, while solving Locke and Latham's issue of time perspective within goal setting [120]. Further studies on exergames which include goals could look at the way time influences motivation. Within the context of iFitQuest, an investigation into motivation with regards to micro- and macro-goals could help future exergame developers correctly balance goal setting with time to maximise motivation.

Self-Determination Theory (SDT) is a theory of human motivation that looks at one's motivation towards a goal, and how much this motivation is inherently energised without any external influence or interference [49]. Importantly, SDT aims to make the distinction between intrinsic and extrinsic motivation, to understand not only the level to which one is motivated, but also why, and what are the implications. Within the context of iFitQuest, SDT could be used to investigate how different often contrasting factors influence the behaviour of the participants. For example, those that were intrinsically motivated by enjoyment, or attaining better fitness, versus those that were extrinsically driven by competition. In relation to self-efficacy, conceptually one of the key elements of SDT, *competence*, has many similarities. Bandura has looked at self-efficacy with regards to motivation type, showing that self-efficacy can be positively correlated with intrinsic interest in a task [19]. Viewing iFitQuest with respect to SDT may provide interesting insight into the different types of motivations being fostered and why. During the iFitQuest evaluations, various intrinsic (improve fitness, improve mini-game scores) and extrinsic (beating friends, coming top of the class leaderboard) motivators were observed. Understanding why certain participants migrated towards certain elements, and how to motivate them in different respects, could prove interesting and useful for future exergame developers, especially those trying to foster greater intrinsic motivation towards physical activity.

Despite these alternative theories, self-efficacy remains the logical choice when considering behavioural change. It has been well tested and validated within a number of domains, and accurately predicted and helped in understanding a number of behaviours within iFitQuest. To revisit the primary research questions, self-efficacy has been used to explain mini-game selection habits, replay and avoid behaviours, as well as why certain participants increased and decreased in-game difficulty settings. Of those that set themselves in-game goals, self-efficacy also accurately predicted and explained the level participants set their goals at, goal-commitment, and reactions to failures within the game.

8.5 iFitQuest: Validating Design Requirements

iFitQuest is one of only a few pervasive exergames deployed into both a high school and primary school context. While practitioners in the field have begun looking at design requirements for exergames in general, none have specifically applied their findings to research-based systems designed for adolescent school children. Therefore, one of the contributions of this thesis is the application of existing design requirements, augmented with new design requirements established from the user-centred design process, for a school-based pervasive exergame.

Before assessing each of the specific design requirements, it is important to consider the design of the system as a whole. Important high-level design decisions, such as the use of mobile location-aware technology, are difficult to assess without comparison to another form of exergame. The negative consequences of such a decision were mentioned when discussing the school ecosystem, such as poor weather having a negative impact on a game of this type. However, there were participants that appreciated the pervasive nature of the experience. A number of participants specifically mentioned they liked the freedom of being outside. Alice stated, "I like how you can play the game but be outdoors". Important social elements were also supported, with pervasive exergames known and appreciated for their facilitation of real world social interaction [94].

With that in mind, in addition to the positive results of the two principal iFitQuest evaluations, it is possible to deduce that the choice of a location-aware mobile game was an appropriate one. The findings summarised within Section 8.4.5 should, in theory, be replicable in all types of exergames. Further work should look at replicating the above findings within other types of exergames.

The adoption of a suite of mini-games was another successful high-level decision. It allowed participants with a wide variety of backgrounds to enjoy the experience, while also supporting various different mini-game types and intensities of physical activity. Although difficult to assess, a session of mini-games was designed to mirror interval type training in which the player does short bouts of physical activity. Further analysis of the accelerometer data (outlined in Chapter Nine) will provide a clearer picture of how participants exercised during a session. However, the analysis presented within this thesis outlines the ability of iFitQuest to facilitate a range of physical activity intensities while preventing sedentary behaviour. One potential shortcoming of the current approach is the lack of moderate intensity physical activity, with participants generally either in the light or vigorous intensity zones. In order to improve iFitQuest, participants should be encouraged from light intensity physical activity into the MVPA zones. By virtue of the fact that iFitQuest contains short sharp burst of activity, this level of physical activity is more difficult to facilitate. Suggestions for achieving more MVPA are contained in the subsections which follow and the future work presented in Chapter Nine.

In the subsections that follow, each iFitQuest design requirement is revisited. Each requirement is outlined along with a description of how it was designed into iFitQuest. An analysis of how each requirement influenced the experience as well as potential improvement for future iFitQuest versions is then given.

8.5.1 Free Play

Free play refers to providing the opportunity for choice to the player. Rather than confine players to a set goal, or a set ordering of the mini-games, players within iFitQuest are given autonomy on how to organise their sessions. The players can select which mini-games they wish to play and in what order.

The evaluation of iFitQuest found this to be particularly effective, with different players making use of free play to suit their needs. Mia chose to organise a session so she could play the more physically demanding mini-games before she became tired, while Isla chose to play the same mini-game repeatedly as part of a training exercise. Low fitness participants, such as Hannah, could focus on low intensity mini-games, while participants with specific tastes, like Daniel, could focus on the mini-games they enjoyed most. As has been discussed, similarly diverse behaviour was observed with goal setting.

Free play was well received and helped iFitQuest appeal to a diverse audience. However, there were examples where too much choice could be interpreted as having a negative impact. David, for example, chose to repeatedly play the Collect the Coins game. This kept him motivated and moving towards his goals, but to the detriment of the amount of physical activity facilitated. Likewise, participants such as Hannah and Sophie, were happy to play the low intensity mini-games without ever really pushing themselves. Future iterations of iFitQuest should thus look at maintaining choice, with some form of session framing for those that require greater encouragement. An adaptive game manager is discussed in Chapter Nine, which could potentially encourage participants towards certain mini-games.

8.5.2 Marginal Challenge

Marginal challenge ensures that mini-games appropriately maximise motivation through challenge level, with each subsequent level providing marginally more challenge. In iFitQuest there are 10 difficulty levels for each mini-game, and participants can custom override difficulty to suit their needs if required.

Throughout the evaluation of iFitQuest, there was evidence to support the fact that marginal challenge was well implemented. Participants identified the fact that there was a progression in difficulty between levels, with those that custom changed difficulty often stating it was to increase or decrease challenge level. While some participants complained that certain mini-games were overall too difficult, the difficulty change between levels appeared well implemented. Log-files showed that the majority of participants were capable of progressing through the levels of the mini-games.

Marginal challenge is one of the best validated design requirements in the field of exergames [7, 32, 203]. Adapted from traditional approaches to physical activity development, it is logical that exergames should look to incrementally improve performance without pushing players beyond their limits. The evaluation of iFitQuest confirmed the merits of this design requirement.

8.5.3 Custom Challenge

Related to the above, custom challenge refers to the fact that players should have a level of autonomy over the challenge levels they face. Within iFitQuest, players are often provided with the opportunity to override difficulty levels to suit their own needs.

Certain mini-games, in particular Collect the Coins, can be played at a whole range of intensities with little impact on performance (maximum points can be achieved by walking or running).

The evaluation of iFitQuest highlighted that, for many, custom changing the difficulty of the mini-games was an unnecessary feature. While some players utilised the feature to provide greater challenge, higher points earning potential or greater chance of in-game success, many participants chose to leave the difficulty changes to the system. However, custom challenge was also inherent in the free choice players had in mini-game selection. Mia planned a session of mini-games around how tired she was, while Jack often played Collect the Coins at high intensities while his peers were walking.

Part of the issue with assessing the ability to custom change the mini-game difficulty levels was the way it was implemented into the system. Players that returned to the main menu or frequently played a variety of mini-games were not given the opportunity to use the feature as regularly. For a full understanding of how custom difficulty can be utilised, further evaluation of the system is required. While custom challenge may not be a useful feature for all players, for many participants in the iFitQuest evaluation it provided the ability to cater the system to suit their goal and background.

8.5.4 Social Play

Many exergame practitioners have emphasised the need for social play within exergame design [32, 39, 203]. Social play looks at encouraging social interaction between players in order to maximise the effectiveness of the game and the experience of the players. In iFitQuest, social play is inherently included through the social aspect of pervasive gaming [94]. Additionally, the support for competition encourages social interaction between peers.

Social play was, in general, a positive aspect of iFitQuest. Discussed within Section 8.3.1 were various examples of competitive and collaborative play providing motivation and enjoyment for the players. There were, however, examples of negative social outcomes, such as ridicule and mocking for low performers, or those that became distracted by their peers.

By encouraging social play within a flexible environment like iFitQuest, it is difficult to control for those that choose to abuse the system. A balance must also be made between social interaction for enjoyment and motivation and that which is causing too much sedentary behaviour. Despite some examples of negative social outcomes, the social aspects afforded by pervasive games provided a key source of motivation and enjoyment for the majority of players. However, one must make careful consideration when deploying the system into a context where an existing social ecosystem is in place, as was discussed within Section 8.2.

8.5.5 Fair Play

Fair play looks at ensuring the game is fair for all participants, and that all players have a level playing field irrespective of their background. iFitQuest provides a range of mini-games that facilitate different intensities of exercise, as well as algorithmically generating points to compare players to themselves rather than their peers.

Fair play is an intuitively sensible design consideration, especially when including the element of social play. Without consideration, players of low self-efficacy and with little background in physical activity may quickly become demotivated if directly competing with more able peers. The iFitQuest evaluations suggest that a level playing field was successfully achieved within iFitQuest. Even though specific mini-games may have been too difficult for less fit individuals, completing other mini-games, earning points, and beating personal bests were all equally likely regardless of background. Hannah with her high placing on the leaderboard was the greatest testament to this.

This design consideration is well understood within the exergaming literature [32, 233]. The findings from iFitQuest confirm this earlier work, establishing the merits of a level playing field as a means to keep players from a variety of background motivated and enjoying the exergame experience.

8.5.6 Personal Awareness

Previous exergame evaluations have established the importance of allowing players to see their activity levels for full appreciation of the exercise they are performing [39]. iFitQuest provided a statistics screen at the end of every mini-game, as well as a main statistics screen which stored details of previous sessions. The points system also provided the player with a simple way of understanding performance.

The iFitQuest evaluations confirmed the need for this design requirement. In particular, participants utilised the simplified points system as a way of judging performance. In extreme cases, e.g. Hannah, participants regularly revisited the main menu of iFitQuest in order to closely monitor their statistics. Participants were less interested in the statistics related to speed and distance, in particular the younger children. There was little mention of these aspects within the post-evaluation questionnaires or interviews, while some participants stated they had never checked their session statistics.

Future work, outlined in Chapter Nine, will look at alternative methods for conveying this information. Younger children may appreciate a simpler interface, designed to convey performance without the specific details. The option for specific details could be included for participants like Isla, who utilised the system as a training aid.

8.5.7 Quick Start

The ability to quickly pick up and play the exergame was an important consideration for helping iFitQuest effectively fit within the heavily time constrained school context. iFitQuest was designed with simple game mechanics, with very little overhead between games or when starting the system.

Based on researcher observations, as well as interview data, it appears that iFitQuest effectively reached this goal. Participants began playing the game almost instantly after receiving their device, and gaps between mini-games were due to external reasons, such as players comparing points.

Relative to the loading time frustrations observed during the requirement gathering focus groups, it was pleasing to note that participants never complained about this aspect of iFitQuest. The quick start requirement also helped maximise the amount of game time during a session, ensuring players undertook as much physical activity as possible. Although such low overhead may not be possible in more advanced exergames, when considering the short attention spans of children, and often constrained school context, designing for a pick up and play mentality was an effective design decision.

8.5.8 Short Bursts

Related to quick start, designing for short bursts of activity was also considered as a way to help iFitQuest successfully integrate into the constrained school context while also accounting for short attention spans. Short repeated bursts of activity is also an effective form of physical activity known as interval training [212]. iFitQuest was designed as a suite of mini-games to meet this requirement.

Given the overall success of the system, and the way it was integrated into two different contexts, both evaluations confirm short bursts of activity as an effective design decision for this type of technology. Based on researcher observations, and the comments of the expert P.E. teacher, the bursts of activity were well aligned with the type of exercise often undertaken within a traditional P.E. class.

Already discussed, there was a lack of moderate intensity physical activity undertaken whilst playing iFitQuest, with players most regularly in either the light or vigorous zones. As iFitQuest was designed as a series of short bursts of activity, intuitively, it makes sense that participants would be performing bouts of light intensity physical activity interspersed with high intensity periods. Future iterations of iFitQuest should encourage participants into less light intensity physical activity and more moderate intensity physical activity. While short mini-games may not be ideal for this form of exercise, adding additional mini-games which require more sustained periods of play, and thus cannot be played entirely at a vigorous intensity, could potentially facilitate more moderate intensity physical activity.

8.5.9 Focussed Activities

During the initial expert interview, the P.E. teacher stressed the need to carefully consider the physical activity being facilitated within an exergame. The expert believed that, in her experience, exergames failed to properly consider different intensities of physical activity. Additionally, games were designed with the physical activity as an afterthought compared to other game elements, such as visuals and story. Within iFitQuest, each mini-game was designed with traditional physical activity exercises in mind, in addition to facilitating different levels of physical activity intensity. The suite of mini-games also mirrored an interval style approach to physical activity.

The data from the accelerometers and the mph estimation method highlights that iFitQuest facilitates a range of physical activity intensities. While no definitive improvements to fitness were noted, anecdotally the P.E. teacher observed that iFitQuest sessions were equivalent to traditional P.E. classes, while the system effectively contributed towards the player's daily physical activity targets and prevented sedentary behaviour.

By considering specific types of physical activity and traditional physical activity exercises, and reverse engineering the mini-games based on the type of movement to be facilitated, iFitQuest was well received by both players and physical activity experts. This approach helps maintain the core focus of the exergame, and in the case of iFitQuest, helped ensure it met one of its primary requirements of facilitating physical activity.

8.5.10 Flexibility

Flexibility comes in various different forms within iFitQuest, from the variety in micro- and macro-goals, to the free choice of mini-games and in-game difficulty. When initially designing iFitQuest, flexibility was thought of as a way to account for the heavy constraints of a P.E. context and the diversity of participants. This was achieved by setting up a session as a number of mini-games, with each mini-game designed in a different way to account for a diversity in player preferences and background.

Evaluating iFitQuest highlighted that this requirement was successfully met. Analysis of the mini-games, and the intensity of physical activity they facilitate, it was established that each mini-game was flexible enough to facilitate a range of physical activity intensities. Likewise, iFitQuest was successfully integrated into two different school contexts and was flexible enough to support external factors, such as weather cutting a session short. Participants of all backgrounds thrived within the iFitQuest evaluations.

The concept of flexibility remains one of the most important design considerations for iFitQuest. By developing the system in such a flexible way, it was possible to deploy the system into two different contexts, targeted towards two different demographics, with success.

8.5.11 Self-Reporting

Self reporting in traditional P.E. classes is a method of encouraging participants to consider their levels of exertion and enjoyment and utilise this when setting goals and making decisions. Within iFitQuest, this was to serve little purpose in-terms of gameplay, but instead was incorporated to aid in the analysis of the system, in particular looking at how enjoyment and fatigue could be linked to in-game events. In iFitQuest participants were asked to rate their enjoyment and level of exertion periodically after playing a mini-game, using two sliders that allowed for values between 1 and 10.

While the self-reporting sliders proved valuable during the prototype evaluations [121], participants in both principal evaluations stated that they paid little attention to the self-reporting method. Even though participants were required to enter a value in order to progress the game, a number of participants stated that they just randomly flicked the slider bars, while some of the younger participants stated they did not know what the bars meant.

In theory, self-reporting could be utilised within an exergame to help participants reflect on their experience and provide in-game guidance. For example, advice on selecting mini-games based on levels of exertion. Although useful in earlier iterations, the self-reporting mechanism was under utilised in the primary evaluations, and as such, was disregarded from the data analysis. When incorporating such a feature, careful consideration must be made for the audience of the game. Younger children may require simpler methods to provide feedback, while designers must get the balance correct when deciding on the frequency with which people are required to report.

8.5.12 Micro-Goals

One of the key considerations for iFitQuest was the idea of small scale goals, or micro-goals. Micro-goals are short term goals designed to give immediate motivation and a clear way to constantly re-evaluate performance. Within iFitQuest, there were a range of micro-goals, such as winning at a mini-game, progressing through the difficulty levels, earning maximal points for a mini-game and achieving personal bests.

As has been discussed in depth within the previous two chapters, participants found a number of micro-goals to be motivating and important. Holly liked it when she moved up to a new mini-game difficulty level, while Jack wanted to see what the highest difficulty was like. Some participants took great joy from winning a mini-game, while others paid no interest. The Mystery Games were also well liked due to the clearly defined goal and the satisfaction that came with setting a new personal best. Micro-goals provided a short term method to evaluate and assess performance. Both Mia and Daniel commented post-evaluation on the effectiveness of this approach and reassurance it provided.

The use of micro-goals was effective within iFitQuest, confirming the findings of prior exergame evaluations [32, 233]. They provide a motivating short term goal for the player, which is particularly important given the flexible nature of school contexts (i.e. rain may stop a session early preventing a macro-goal being reached). While Macro-goals may provide the greatest motivation, micro-goals allow players to more readily track their progress and help in providing enjoyable and satisfying in-game experiences.

8.5.13 Macro-Goals

Related to micro-goals, iFitQuest provided a number of potential macro-goals. These were targets that looked beyond the short term, considering the session, or evaluation, as a whole.

While iFitQuest supported a number of different macro-goals, the most readily adopted were winning the class leaderboard (Jack, Ross, Hannah and David), improving mystery game personal bests (e.g. Mia), and beating weekly points totals (Holly, Hannah and David). One external macro-goal, a desire to improve fitness, was regularly identified as an important motivator, even though there was no inherent support for fitness tracking in the system.

Looking at the experiences of the participants, those that adopted macro-goals generally maintained the greatest level of motivation during the evaluation and had the greatest exergame experience. When the novelty of the mini-games began to wear off, those with a strong desire to achieve their goal maintained high levels of motivation. Therefore, based on the results of the iFitQuest evaluations, macro-goals are another important design consideration. As is discussed within Section 8.4, future iterations of iFitQuest should look at encouraging participants to adopt macro-goals, as well as providing formal methods to track macro-goal progress. It is hypothesised that this would help maintain motivation and potentially combat novelty effects.

The adoption of clearly defined macro-goals, in particular points targets, or personal best improvements, were more prominent during the second principal evaluation. This is likely due to the more frequent nature of play, i.e. it was easier for participants to remember points targets session to session. This adds further weight to assertion that in-game facilitation of goal setting would be a worthwhile development.

8.5.14 Open Environment

An open environment was included within iFitQuest as a means to encourage emergent behaviour, such that the primary research questions could be answered. To provide a platform for an emergence of behaviour, players were given the option to choose what mini-games to play in a session, what difficulty level they wished to play certain mini-games at, and what goals (if any) they wished to set themselves. The notion of an open environment is similar to that of flexibility and free play, but was considered from a researcher point of view to allow for greater investigation into the research questions of the thesis.

Through an analysis of the two primary evaluations, it is clear that this design requirement was effectively met. The case studies outlined in the previous two chapters highlight the different ways participants used iFitQuest to suit their needs.

One can argue whether such an open environment is optimally effective for an exergame. While it encourages a diversity in behaviour, it may not support all users in achieving an optimal experience. Ideally, an exergame could allow participants to express themselves, learn where they draw the greatest motivation, and then adapt to suit their needs optimally. For example, David would be set ever increasing points goals, with the higher intensity games adapted to give him the greatest number of points. Daniel would have a game with a stronger narrative, and clearer goals, playing on his desire for games with a 'point'. In Chapter Nine the potential for an intelligent architecture is discussed, which could facilitate such dynamic play. However, as a means to encourage behaviour, and appeal to a wide demographic, an open environment is an effective choice.

8.5.15 Variable Environment

One important consideration that arose from the second prototype evaluation was the need for variety. By providing variety in the gameplay, the hope is that an exergame can appeal to as wide a demographic as possible, as well as combating novelty effects that may potentially arise from playing the same games repeatedly. Within iFitQuest, eight different mini-games were provided to the player, each with a variety of difficulty levels, game features and type of physical activity facilitated.

Although the participants appreciated the variety, many focussed their attentions towards particular mini-games. A number of the mini-games received very little play, primarily due to their difficulty. While Collect the Coins was the focus for many participants, there were examples that highlight the need for diversity. Participants like Daniel and Isla regularly focussed their attention towards games that were infrequently played by their peers. The next iteration of iFitQuest should try to improve the least played mini-games.

Despite the two principal evaluations being held in different school contexts with players from different backgrounds, there was great consistency between evaluations in both game selection habits and preferences. While a novelty effect may have been present within the longer evaluation, anecdotal evidence as well as log-file analysis showed that even those with strong preference towards particular mini-games branched out to try other mini-games in the suite. As long as overarching goals are present to maintain motivation and continuity, a varied experience is bound to prove beneficial in terms of combating novelty effects and maximising motivation and enjoyment.

8.5.16 Final Design Requirements

Table 8.1: Final list of validated design requirements, established from the development and evaluation of iFitQuest.

Design Req.	Meaning
1. Free Play	Provide the player with the ability to choose their own path while playing the game. Rather than restrict or confine the player, allow the player freedom to control elements of their experience. A form of session framing can allow the player to remain in control of their game, while helping to ensure that players cannot abuse their control.
2. Marginal Challenge	Ensure motivation by appropriately controlling the challenge level of the game. Marginal increases in difficulty between levels or mini-games can provide an effect source of motivation while helping to increase the level of physical activity facilitated by an exergame.
3. Custom Challenge	As one element of the free choice requirement, as well as recommending difficulty levels, the player should have the ability to customise the level of challenge within the game. This additionally flexibility can help accommodate different player motivations while allowing for interesting patterns of emergent behaviour.
4. Social Play	Design the game to encourage social play. Well understood within the field of exergames, and more generally within behavioural psychology, social play can form a key factor of player motivation during exergame play. However, careful consideration of the exergame context and type of social play facilitated must be made.
5. Fair Play	When encouraging a social element, whether directly through game design or indirectly through evaluation context, special consideration for a level playing field should be made. All players should be treated fairly and have equal opportunity for success within the game. A disjoint in this element can cause demotivation and dissatisfaction in low performing players.

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Table 8.1 – continued from previous page

Design Req.	Meaning
6. Personal Awareness	Provide players with the ability to see their activity levels. This ensures that players are aware of the physical activity they are performing and reassured that they are getting proper credit for their efforts. The way in which this information is presented will be dependent on other exergame design decisions and the target audience for the game. When working with children, raw physical activity data may be undesirable for some children, with other performance metrics, for example points, providing more relatable feedback.
7. Quick Start	In order to flexibly meet the constraints of a school curriculum, in addition to the shorter attention spans of adolescent children, the game should be designed with a ‘pick up and play’ philosophy. This will help ensure that children can receive the benefits of playing the game as quickly as possible during a session.
8. Short Bursts	Short, sharp bursts of physical activity interspersed with periods of lighter intensity physical activity can prove effective within exergames. The bursts of activity help promote periods of MVPA while the rest periods help target the shorter attention spans and lower fitness levels of adolescent children. The rest periods also help promote social play, by providing a period for children to communicate with one another. Such an approach to game design may be better suited to light and vigorous physical activity, rather than prolonged moderate intensity physical activity.
9. Focused Activities	Focussing the design of an exergame on specific elements from physical education is an effective method to help ensure that an exergame helps promote appropriate levels of physical activity. By building upon fitness principles, and ensuring that game content and themes are appropriate to the physical activity goals of the system, the focus of the game is maintained.
10. Flexibility	Given the importance of intervention context on the success of a system, and the differing needs and desires of any target demographic, exergame developers must strive for flexibility when designing their system. A flexible system that can target greater demographics and fit within a number of contexts are more likely to succeed. Examples of flexibility include providing multiple in-game goals and designing sessions to accommodate different periods of play time.
11. Self-Reporting	With children taught at a young age to critically assess their physical exertion and performance, self-reporting can potentially allow for valuable insight into the experience of the player. However, careful consideration on how to facilitate this data gathering must be made, as laborious or persistent input screens may break the immersion of the player.

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Design Req.	Meaning
12. Micro-Goals	Short, small scale challenges and goals are an effective source of motivation for the player and provide a regular feedback mechanism. Allowing the player to choose from and strive towards a number of micro-goals within a session is an effective way to motivate players and encourage physical activity. Micro-goals should be goals that can be achieved over a short period of time, for example a single gaming session.
13. Macro-Goal	In addition to a number of micro-goals, the game should contain an overall goal which ties each individual gaming session together. This larger scale macro-goal will provide the player with a long term target to work towards and help maintain persistent motivation across the length of a study. Effective macro-goals are both achievable, yet challenging. Consistent with previous requirements, a macro-goal should be achievable by all players, and suited to the background and motivation of the player. A number of macro-goals is one method to meet the requirements of flexibility and free choice.
14. Open Environment	By meeting the requirements of flexibility and free play, the player is provided with an open environment in which emergent patterns of behaviour are encouraged. Allowing players to mould the experience to suit their own wants and needs is an effective way to ensure prolonged motivation and enjoyment. From a research perspective, it allows for interesting insight into how different player behave. An overly constrained environment may impact the behaviour of the participants. In terms of exergame design, allowing for emergent behaviour may not be optimal in cases where players require additional encouragement to perform physical activity. An important consideration for game designers is the extent to which an open environment is provided, too much control and choice may be sub-optimal for some players, while heavy constraints may alienate certain demographics.
15. Variable Environment	Consistent with basic game design theory, variety is an effective method of maintaining the attention and motivation of the player. Within the context of exergames, variety can also allow a single exergame to target different elements of physical activity. Additionally, variety in game content and style can potentially appeal to a wider set of player requirements. Game designers should design for maximum variety while providing a consistent theme and style, to ensure continuity across the duration of an exergame intervention.

8.6 Logistical Lessons Learned

8.6.1 User-Centred Design for Exergames

One of the significant early decisions in the process of developing iFitQuest was the adoption of a prototype driven user-centred design process. While it is difficulty to empirically evaluate such a process, the positive reaction to the final system, and the emergence of a number of design requirements from the users, highlights that the approach was successful.

During the user-centred design process, it is important to consider all users of the system. When developing an exergame for a school context, teachers themselves are as much an end-user as the children [132]. This makes exergame development a balancing act between the constraints of the environment, the demands of the children, and the requirements of the teacher. An iterative prototype driven approach is an effective way of addressing this tension. During the development of iFitQuest, sceptical teachers became more enthusiastic having seen a prototype. This is particularly important considering teachers must sign up to allow their class to evaluate a system. Russell highlights the need for teachers to be knowledgeable, comfortable and experienced in using exergame technology in order to effectively integrate it into their curriculum [174]. A user-centred design approach was found to be an effective way of highlighting the benefits of technology to the teacher and removing preconceived notions on the effectiveness of such technology to facilitate physical activity.

While requirements were established, idea generation was harder to facilitate during the end-user focus groups. An effective technique was to allow the children to play a sample of exergames as a way of providing a reference point. Multiple exergames allowed for comparisons, which helped draw out preferences, and thus favourable elements. Such an approach is similar to the well established *Laddering* approach outlined by Zaman and Abeele [235]. As was discussed in Chapter Four, the influence of the school ecosystem was also made clear during the focus groups, with females apprehensive to participate in-front of their male peers. Practitioners must consider the potential implications of this when designing their user-centred design approach. While the feedback from the focus groups greatly aided the design, the children worked best as *Design Informants*, providing ideas and outlining requirements without directly designing the iFitQuest system as equal stakeholders [56].

Based on the findings of the iFitQuest evaluations, adopting a prototype driven user-centred design approach is a sensible choice when developing exergames for a heavily constrained context. By including users from the target player group, teachers, and physical activity experts throughout the process, a set of design requirements were established that effectively met the needs of the end-users. While techniques can be employed to understand the general requirements of children, practitioners must remember that children are not expert designers or developers and may have little to no experience of the genre. Laddering techniques employed on existing exergames can tease out requirements, while regular prototypes allow children to constantly re-evaluate and provide more valuable feedback.

8.6.2 The School Context

Early on the design process, the heavy constraints of the school context became clear. Despite high school children receiving a minimum of 1 hour of P.E. classes per week, the amount of actual physical activity performed within this time was significantly less. Based on the findings of the first primary evaluation, children were active for on average only 30 minutes per session, with approximately 10 minutes of that reserved for warm-ups and cool-downs. This is consistent with the researcher observations of traditional P.E. classes and the findings of Sallis et al. [179].

Given the timetabling constraints of a high school context, it is difficult to achieve any more physical activity within the time slot. While all physical activity is beneficial, exergames designed for high school contexts should look to maximise the amount of MVPA facilitated in order to provide the greatest contribution towards physical activity guidelines. The feedback from the high school evaluation suggests that iFitQuest is well suited to a P.E. classroom.

Integrating and evaluating iFitQuest into a primary school context proved more simple. If the weather was unkind, or plans changed, iFitQuest could be easily rescheduled into the day. The aforementioned design requirements meant that iFitQuest could quickly be stopped, restarted, extended or shortened to suit the needs of the teacher. Within a primary school context, iFitQuest could be used as part of a greater health and fitness intervention, with participants regularly using the system for a predefined period of time, as well as receiving additional support and learning material, like for example [35].

When designing iFitQuest, careful consideration for the constraints of a school context were made. Proposed in Chapter Nine is a larger scale cluster randomised control trial. An evaluation of this scale would further validate the ability of iFitQuest to integrate effectively into disparate contexts.

8.6.3 Lessons on Exergame Evaluation

Based on the findings of the two primary iFitQuest evaluations, a number of important lessons on exergame evaluation emerged. First, the need to evaluate a system in-situ and longitudinally was made clear from the interesting in-game behaviours of the participants. It was only through the prolonged nature of the evaluation that many emergent behavioural patterns became clear. For example, the participants' goal setting behaviours. Further to this, a single evaluation would have given a misleading account of how participants really felt about the system. An exemplary case being David, who found his first use of the system frustrating and unenjoyable. While single evaluations are perfectly suited for pilot testing and prototype development, prolonged use of the system is required to fully understand the exergame experience. Additionally, evaluation must be done in-situ. This is strongly reinforced by the discussion on the influence of the social ecosystem on the exergame experience. Without actually deploying iFitQuest within a school context, this influential factor would have been lost and the results of any evaluation misleading.

Building upon this, qualitative data methods, in particular interviews and researcher observations, are essential in establishing some of the more salient yet subtle behaviours and actions. Had it not been possible to supplement the raw data gathered from pre- and post-evaluation questionnaires and in-game log-files, much of the discussion on participant behaviour would have been lost.

8.6.4 Instruments for Exergame Evaluation

Through evaluating iFitQuest, a number of logistical lessons were learned with regards to evaluation instruments.

The questionnaires largely produced valid and useful information. By comparing the questionnaire data with other feedback, there was predominantly a consistency in the answers which validated the use of the questionnaire. However, as was highlighted in Chapter Seven, there were examples where participants appeared to misunderstand the questions, as well as examples where log-file data contradicted the results given. Placing a researcher with participants could help clarify confusing questions, but would likely influence the feedback provided. As these issues were only present with the younger children, alternative data gathering techniques could be considered. For example, the *Fun Toolkit* [168], or using a *Laddering* method [235].

A mixed-methods approach proved particularly useful for supplementing questionnaire data. Children in both evaluations were unlikely to fill in the blank space questions or explain their answers. Post-evaluation focus group discussions and interviews were useful for clarifying points and adding depth to the answers.

When designing questionnaires, one must be sure to consult experts in that demographic to ensure that vocabulary and techniques are appropriate for such an audience. In addition, questionnaires and instruments must be catered to the specific school. The primary school used for the iFitQuest evaluation had lower standards of attainment for English and mathematics, which could in part explain some of the difficulties in answering the questionnaire [60].

In the previous chapter, the merits of using accelerometers to measure physical activity were discussed. In Chapter Three, examples of evaluations which used similarly well validated measures of physical activity, such as heart rate monitors, were discussed. The merits of such approaches were made clear within the second exergame evaluation, with accelerometers providing the clearest insight into how iFitQuest facilitated physical activity. Based on the additional time required to set up such devices, and the heavily time constrained contexts, future exergame evaluations should utilise such technology, but only on occasion, so as not to regularly distract from the physical activity itself.

The final instrument meriting discussion was the Bleep Test. As was outlined in the previous chapter, the test produced inconsistent results that were heavily influenced by the social culture of the school. Alternative, potentially more valid tests, such as the *FITNESSGRAM* [155] were suggested. One must still consider the potential impact of the school ecosystem, irrespective of the instrument adopted. In addition, while fitness testing may provide further validity to any assertions on the effectiveness of an exergame, one must consider the fact that other measures of success are available. The evaluation of iFitQuest highlighted the need for multiple methods of evaluation in order to fully understand the exergame experience.

8.7 Summary

This chapter collated the primary discussion points from the two principal iFitQuest evaluations as a means to discuss the success of iFitQuest, as well as understand in greater depth the exergame experience.

iFitQuest was designed as a location-aware pervasive exergame for use within a school context. Based on the evidence of the two principal evaluations, it can be concluded that these goals were met. Participants found the experience enjoyable, motivating, and physically demanding, while the system was seamlessly integrated into two differing contexts with equal success. Based on the success, the primary design requirements were revisited and validated, providing practitioners who wish to design and develop exergames for this context or demographic with a set of guidelines. Where the design requirements were not fully met, or possibly not optimal, further evaluation or improvement to the iFitQuest system are suggested.

Core to the central discussion of this thesis, the in-game exergame experience was discussed by looking at a number of key concepts as well as the influence of self-efficacy on the motivation and behaviour of the participants. The results of these evaluations highlight the need to consider self-efficacy when both designing and analysing exergames, due to its considerable role in the behaviour of the participants. By influencing the motivation of the players, self-efficacy should be considered by future exergame developers as a means to develop more enjoyable and motivating exergame experiences.

Based on the understanding of self-efficacy and the exergame experience, future exergame practitioners can, it is hypothesised, begin to develop more effective exergames. Using the lessons outlined within this chapter, the goal of future versions of iFitQuest is to appeal to a higher percentage of the players, facilitate more MVPA, and maintain interest and motivation for longer such that there is minimal, if any, novelty effect. However, important considerations must be made to the context of the evaluation and the way a social and cultural ecosystem can influence an experience, regardless of system design. The presence of such an influential external factor, as well as the need for time in properly understanding behaviour, both highlight the need for exergame evaluations to be run in-situ and longitudinally in order for the future of exergames to reach their potential and fulfil their goals.

Based on the discussion presented within this chapter, Chapter Nine focuses on potential avenues for future work.

CHAPTER 9

Future Work

Throughout this thesis, a number of ideas for potential future work have been identified. The need for further empirical work with iFitQuest was identified in the previous chapter as a means to build upon the findings of this thesis, and begin generalising findings across greater populations. In addition to this, potential changes for future versions of the iFitQuest system have been identified, some of which are designed to improve the system based on the findings of the two principal evaluations; others are designed to open further avenues for empirical evaluation. This chapter develops these ideas in more depth and outlines some of the current work already being undertaken.

9.1 Ongoing Work

One potentially interesting piece of data not fully explored within this thesis is the accelerometer data provided by the tri-axial accelerometers, used in the final session of the second principal evaluation. While the data was examined to provide an overall picture of the participants' physical activity levels for that session, not investigated within this thesis is the detailed breakdown of physical activity level with time. By comparing the accelerometer data time stamps with those of the iFitQuest log-files, it is possible to establish the physical activity level of each participant at any given time and correlate this with their behaviour within iFitQuest. As was discussed within Chapter Seven, the tri-axial accelerometers provide the most accurate and valid understanding of physical activity intensity. Additionally, the accelerometer time stamps provide a second by second outline of physical activity levels, where as iFitQuest logs provide averages for each mini-games and do not account for activity done outwith a mini-game.

The accelerometers can thus provide a clear overview of how each mini-game facilitates physical activity, and how it contributes to the overall physical activity of each participant. By understanding how each mini-game contributes towards the suite as a whole, this data could be used when iterating over iFitQuest to increase the effectiveness of the system at facilitating physical activity.

This data could also be used to establish optimal session lengths. By looking at trends of physical activity data, it may be possible to establish times where the player becomes too demotivated or tired to continue effectively play the game. By adapting session lengths, or adding extra incentives at times of low motivation or activity, it may be possible to facilitate more physical activity in an iFitQuest session and greater long term motivation in the system.

Additionally, by correlating accelerometer time stamps with the iFitQuest logs, it would provide a detailed picture of how participant behaviour affected their physical activity. For example, how did increasing or decreasing difficulty actually impact upon physical activity intensity, or how much additional physical activity did those participants that played cooperatively in the Mystery Games actually get? The above are just two scenarios in which accelerometer data would usefully augment the findings of this thesis.

Ongoing work is being done on the log-files collected during the two principal evaluations. In Chapter Eight a number of interesting in-game behaviours were discussed. These findings were based on both observational data, self-identification from participants within questionnaires and interviews, and log-file analysis. Building upon this, log-files are being sequentially analysed in order to construct state transition diagrams. By creating state transition diagrams, it will be possible to establish the probability that a certain behaviour (e.g. increase or decrease difficulty, or replay a mini-game) is likely to happen, correlated with the participant's self-efficacy background. This will allow for quantitatively validated insight into the way self-efficacy influenced participant behaviour, providing more evidence in addition to that already presented within this thesis, on the impact of self-efficacy within exergames.

9.2 Future Empirical Work

9.2.1 Long Term Effects of iFitQuest

The results of the two principal iFitQuest evaluations highlighted its potential for facilitating physical activity within a motivating context, although there is potentially an issue with system novelty over longer evaluations. In order to properly validate the exergame, further evaluation is required. This would provide both greater validity to the existing findings, as well as answer questions on the long term effect iFitQuest has on its players.

iFitQuest should be evaluated as part of a cluster randomised controlled study, involving a number of participating classes as well as control groups with which to compare results. A large scale evaluation of this sort would allow for more concrete conclusions to be drawn on the effectiveness of iFitQuest as a tool for physical activity interventions. In particular, comparisons with control groups could be used to quantitatively evaluate how iFitQuest affects the attitude and physical fitness of the participants.

Such evaluation would also be done over a more prolonged period of time and include follow up visits for over a year after the end of the initial evaluation period. As well as further assessing potential novelty effects, more prolonged use of the system would allow for further measure of the potential of iFitQuest to positively impact the player. Additionally, follow up visits would provide data on the long term impact of iFitQuest. This would not only provide evidence on the success of iFitQuest, but given the lack of longitudinal evaluation in the field, also greatly improve the field of knowledge on exergames.

Further to the above Ongoing Work, and discussed in the previous chapter, utilising tri-axial accelerometers more regularly would allow for more data on the way iFitQuest facilitates physical activity. By adopting such an approach as part of a longitudinal randomised controlled trial, this validated physical activity data would complement any findings on changes to fitness levels. Additionally, viewing the data over time would provide an additional data stream for measuring novelty effects.

One final direction which requires further investigation is the anecdotal evidence that those participants that had the least motivation for iFitQuest were those that also had low motivation for traditional P.E. and physical activity, as was observed by the expert P.E. teacher. As this describes a small subset of the participants, this may be due to the attitude of these particular participants. One additional advantage of a cluster randomised controlled trial would be further understanding on how exergames can appeal across a whole demographic.

9.2.2 The Application of Self-Efficacy to Exergames

In the previous chapter, the implications of self-efficacy for exergames was discussed. While iFitQuest was designed and evaluated with a specific demographic and context in mind, these findings are in theory applicable to other areas of exergames. In order to investigate this, formal evaluation of self-efficacy within other exergame systems and for other demographics is required. One potential direction for future evaluation is to aim to replicate the findings of this thesis within console based exergames, for example the Wii Fit. Additionally, replicating the results discussed within this thesis with an adult demographic would further generalise the results.

9.2.3 Formal Evaluation of the Design Requirements

One contribution of the work within this thesis is the list of design requirements adopted for the development of iFitQuest. Established from the related work in the field and the user-centred design process, the requirements were validated through the general success of iFitQuest as well as the discussion on how each individual requirement contributed towards the overall success of the system.

However, as was discussed in the previous chapter, minor alterations to some of the requirements could lead to a more optimal exergame experience. Additionally, while the two principal iFitQuest evaluations provided some validation to the requirements, a larger scale evaluation of the type discussed within Section 9.2.1 is required to fully validate the findings. Given the influence of context on the success of a physical activity intervention, dissemination of iFitQuest into a greater variety of schools would add insight into the generalisability of the requirements.

9.2.4 Alternative Theories of Motivation

In the previous chapter, the justification for using self-efficacy was discussed and validated. However, alternative theories to behavioural motivation were discussed, in particular, Self Determination Theory [49], which aims to investigate different sources and types of motivation. One potentially interesting direction for future empirical work is understanding why some players were drawn towards certain motivating factors, in particular the contrast between intrinsic and extrinsic motivation. Having such understanding could aid future exergame practitioners in catering their games towards a certain type of motivation, or ensuring that their system has appeal towards people of a particular background.

9.3 Possible Adaptations of iFitQuest

Based on the findings of the two principal evaluations, a number of potential improvements and adaptions for iFitQuest were identified. Before undertaking any further empirical evaluation, updating iFitQuest to a more effective system is the intuitive next stage in the process. The following changes are outlined as potential ways to improve iFitQuest, without impacting upon the elements of iFitQuest found to be particularly successful.

9.3.1 Support for Goal Setting

Highlighted in the previous chapter, the self-setting of goals was heavily associated with a successful iFitQuest experience, in terms of in-game performance, motivation and enjoyment. As was discussed, given the sound understanding of goal setting theory, the adoption of goals and resultant positive influence is not surprising. Thus, one potential improvement to iFitQuest is to formally support the setting of goals, through an in-game system which could help a participant decide upon, track and manage their goals.

By suggesting potential goals from the list of available micro- and macro-goals, and providing statistics (for example previous performance) to aid in goal setting, this could encourage more participants to adopt goals, and consequently, in theory, maintain greater motivation. Such a feature would also make session to session tracking of goals more straightforward. In the current version of iFitQuest participants knew their overall points and current session points, but they could not see their previous sessions points total. Those that set points goals had to remember their past performances themselves. Formal goal setting would alleviate this issue. Finally, formal goal tracking would allow participants like Daniel and Hannah, who were obsessed with checking their total points, to spend more time on playing the mini-games rather than returning to the main menu to ensure points have been correctly added. Using a basic model of the player, such a system could help set goals in an attempt to set optimally motivating targets. By understanding past performance, as well as self-efficacy, iFitQuest could advise on future goal levels.

Adopting formalised goal setting would add a number of potential directions for future empirical work. A recommender system that considered self-efficacy would add weight to the recommendations in Chapter Eight by allowing for empirical evaluation on the way self-efficacy can be harnessed for more motivating exergame experiences.

The use of goal setting, while previously considered within exergames [144], could also be empirically evaluated as a potential mediator for novelty effects and facilitator of prolonged exergame enjoyment.

Another potential area for future empirical work is the impact of self-set versus imposed goals and the implications this has within exergames. While well understood in the psychology literature [116, 117, 119], such investigation has not been done within exergames, and would prove useful for exergame practitioners wishing to implement goal setting into future systems.

Finally, within the previous chapter, Steel and König's Temporal Motivational Theory was discussed, in particular, the influential factor of time with respect to goals and motivation [197]. By implementing formalised goal setting, with support for both micro- and macro-goals, one direction for future empirical evaluation could assess how motivation differers with respect to the type of goals adopted, and how self-efficacy fits within the equation.

9.3.2 Adaptive System

Building upon the above support for formalised goal setting, a natural progression is to re-implement iFitQuest as an intelligent, adaptive exergame. The disparate behaviours, observed throughout the evaluations, outlined the way players utilised the flexibility of iFitQuest to suit their needs. However, while flexibility allowed for emergent behaviours, it also potentially led to a less optimal experience for some. An adaptive system could be intelligently catered to the needs of the player while providing more support for an optimal experience.

An intelligent adaptive architecture would be able to provide recommendations to the players through a model of the player which contains their self-efficacy profile and past performances in the game. Using this information, goals could be recommended at an optimal level to maximise motivation, while also considering how far to push a participant based on the potential implications of success and failure. As well as aiding goal setting, adaption could be used to hide or promote certain features based on the background and preferences of the player. Two potential scenarios are outlined below to highlight the potential success of an adaptive iFitQuest, based on case studies from the two primary evaluations.

Hannah, from the second evaluation, was heavily motivated by points; she set herself an unmoving, readily achievable, goal of 100 points per session, while also sticking primarily to the low intensity mini-games she knew she was capable of winning. Knowing this background, iFitQuest could adapt in certain ways to suit her needs. Having supported her in self-setting an initial goal of 100 points, the system could begin suggesting gradual increases session by session, based on known performance in previous sessions. For example, if she consistently reached 100 points, her next goal could be set at 102 points. This higher goal should in theory result in higher motivation and performance [116, 118], while its achievable nature would account for her low self-efficacy and the potential implications of failure. In terms of mini-games, her desire for points (established from her selection of micro- and macro-goals) could be used to persuade her into playing other mini-games, for example points bonuses for trying new games. Difficulty levels could also be altered and hidden from her, so that the new games she plays require greater physical activity, while remaining winnable.

Another scenario focuses on Isla from the first principal evaluation. Isla had no interest in points or competition. She played mini-games based on how much she enjoyed them, as well as utilising iFitQuest as a training aid. An adaptive system would completely remove the elements that provided no motivation to Isla. Points would be removed, while her presence on any class leaderboards would also be hidden. These elements could be inferred from micro- and macro-goal selection, as well as manually controlled by researchers based on observations of Isla. Additionally, Isla's use of the system as a training aid could be helped through goal setting and tracking, as well as encouraging certain mini-games and highlighting how she can improve within them. Thus, while some participants get given points at the end of a mini-game, Isla would get more detailed information on her current and past performances.

To summarise, the flexibility of iFitQuest allows for a number of emergent behaviours. Without the need for significant change to the system, an adaptive agent could hide or emphasise certain game elements, as well as provide guidance and suggestions based on an understanding of the background of the participant. Utilising this in conjunction with the aforementioned support for goal setting, provides a potential improvement to iFitQuest which could lead to more sustained motivation and more MVPA.

Such systems have begun to be investigated, for example Berkovsky et al's. work on a recommender system for exergames highlighted adaption significantly affected both enjoyment and physical activity in a positive direction. The system was, however, only investigated in a single session and with a less complex adaptive architecture (no consideration for self-efficacy) [24]. Implementation of an adaptive element would provide another direction for future empirical work, of great interest and of potential use to the exergame community.

In order to realise the goal of an adaptive version of iFitQuest, a data-driven machine learning approach could be utilised. Such an approach was recently used by Kim et al. to accurately predict energy expenditure in real time during exergame play [101]. As was discussed in Section 9.1, the log-files recorded during iFitQuest play provide a rich insight into the behaviour of the players. Using this data as part of a machine learning process could potentially allow for an adaptive system capable of making the changes outlined in the aforementioned scenarios. One such machine learning approach is data-driven reinforcement learning. Reinforcement learning has effectively been used within Spoken Dialogue Systems [113] as well as within game theory to predict how people will play games [63]. Use of reinforcement learning would be particularly appropriate given its use of a state transition approach, consistent with the ongoing log-file work outlined in Section 9.1. As the iFitQuest system can be viewed as a series of states and actions (selecting a certain mini-game, customising the difficulty, etc) reinforcement learning could be used to establish optimal states and actions for each player.

9.3.3 MVPA

A lack of moderate intensity physical activity is one potential shortcoming with the current version of iFitQuest. If the system could successfully encourage participants to spend a greater portion of their time in moderate, rather than low intensity physical activity, iFitQuest would combat both sedentary behaviour, as well as contributing more towards physical activity guidelines.

The above two subsections highlight potential approaches to facilitating more MVPA. A formal support for goal setting, implemented with an adaptive system, could be utilised to encourage participants to exercise at a higher intensity. For example, by understanding David's background and desire for points, an adaptive system could begin to award more points for the higher intensity games. This could persuade him away from the low intensity games he only played for point collecting purposes.

In the previous chapter, some more minor alterations were also discussed which could potentially increase MVPA. First of all, adding mini-games that must be played over a greater period of time is one method to facilitate more MVPA. Additionally, eliciting feedback on the least popular games, and making improvements to encourage more play, would potentially prevent players from focussing on the generally low intensity mini-games.

The Mystery Games proved popular as well as successfully facilitating MVPA. However, due to the fact players had to 'unlock' them, they were not always available to play. Unlocking the mini-games was identified as both enjoyable and motivating for some participants, therefore, making the games always available is not a desirable design decision. However, adding more mini-games to the suite that have simplified game mechanics, would provide players with the opportunity to play mini-games of a similar style to the Mystery Games, while maintaining the positive aspects of the Mystery Games such as the random game assignment and need to unlock them.

Supporting different types and intensities of physical activity, and providing a variety in mini-games, were both identified as important features of iFitQuest. Therefore, it is important to maintain the current variety and flexibility, removing low intensity games, or changing existing games such as Collect the Coins, such that they only support higher intensity exercise would negatively impact the success of iFitQuest. Collect the Coins played at a low intensity provides a mini-game to those of low fitness or those who are tired from the session. Rather than remove Collect the Coins completely, participants should instead be encouraged towards higher intensity mini-games more frequently. Thus, changes must focus on additional mini-games and improvements to those least popular in the current version of the system, as well as encouraging participants towards higher intensity mini-games.

9.3.4 Minor Changes

A number of minor adaptions to the iFitQuest system are suggested as a way to improve the experience, as well as add further dimensions for empirical evaluation.

As was outlined within Chapter Six and Chapter Seven, due to the way that custom difficulty setting was implemented into the system, some participants very rarely had the opportunity to utilise this aspect of the game. In the current version of iFitQuest, participants are only offered the chance to custom override difficulty levels if at the end of a mini-game they chose to replay the same game using the 'replay' button. Thus, participants that return to the main menu between mini-games (even if they play the same mini-game again) and those that varied their mini-game selections, could not custom override difficulty. While interesting behaviour was still observed with regards to self-efficacy and difficulty setting, more data would have been available had participants more consistently been given the opportunity to change difficulty. Thus, future versions of iFitQuest should ask participants at more regular intervals, and across as many mini-games as possible.

While effective during the prototype evaluations, gathering in-game enjoyment and exertion feedback was ineffective during the prolonged evaluations. Participants began to ignore the input method, finding it a distraction from playing the mini-games. While a sliding scale from 1 to 10 (as was used for all evaluations of iFitQuest) provides richer data, a simpler binary mechanism could encourage participants to provide feedback. An example would be, "Having played that mini-game, did your enjoyment go up or down?", with a simple interface showing an up arrow and a down arrow. This would be quicker than using a sliding bar, and while less detailed, would still allow for analysis on how attitude changed with time.

Another potentially effective way of simplifying the interface comes with regards to the post mini-game performance feedback. Many participants had no interest in their average speed, or distance travelled, instead focussing simply on their points earned or the game outcome. One improvement would be a simpler message with associated graphic, for example, "You ran even faster than the last time you played this mini-game, well done!" with an associated smiling face. This would explain why a certain number of points was earned, without providing unnecessary detail. A setting to return to the more detailed feedback would be available for those that wished to see the details of their performance.

Within Section 9.2.1, the desire for more concrete evaluation of fitness improvements was discussed. One potential improvement to iFitQuest which could facilitate data gathering would be the addition of in-game fitness testing. In-game fitness testing would help maintain immersion within the system, as well as avoiding the problems observed with regards to social influence during the Bleep Test. Additionally, within an adaptive version of iFitQuest, this data could be one further element of the player model, acting as one further consideration when recommending adaptions. The fitness tests suggested in Chapter Seven and Chapter Eight could potentially be integrated into the system.

9.4 Summary

This chapter has outlined some suggestions for potential future adaption to the iFitQuest system, as well as directions for future empirical work.

The contributions of this thesis extend the body of knowledge that exists on the potential application of exergames. However, further evaluation of the iFitQuest system is required to fully validate and generalise the findings, as well as extend some of the more tentative conclusions. Thus, the primary suggested direction for future work is a large scale randomised controlled study, conducted over a more prolonged period of time.

In addition to this, through the two principal evaluations, a number of potential improvements to the iFitQuest system were identified, each of which could serve to provide a more effective exergame experience. Through the adoption of an adaptive architecture, and more formalised support for goal setting, iFitQuest could support the same variety of behaviours from within a more optimal environment. While also improving iFitQuest, each alteration and addition would widen the scope for potential future empirical work, with the merits of adaptive architectures and goal setting not fully understood within exergames. Importantly, the findings presented within this thesis, in particular with regards to self-efficacy, can be utilised in this future development work to, it is hypothesised, develop more effective exergames.

CHAPTER 10

Conclusions

This chapter summarises the primary contributions and findings of the work presented within this thesis. These are related back to the research questions which provided the direction for the work, after which the thesis is concluded with a final summary.

10.1 Contributions

The primary contributions of this thesis can be summarised as follows:

- *A review of health and fitness literature highlighting the need to promote more physical activity, and less sedentary behaviour, in adolescent children.* As well as highlighting the need for physical activity interventions, the merits of using self-efficacy as a means to understand behaviour as well as promote more physical activity and less sedentary behaviour was discussed.

- *A concise literature review on the field of exergames, highlighting the need for more longitudinal, in-situ evaluations geared towards an adolescent demographic.* Additionally, the literature review provided justification for adopting a location-aware pervasive exergame, as well as the need to better understand the exergame experience.

- *A set of design requirements, geared towards effective school-based exergames for an adolescent demographic, that resulted in the successful development and deployment of iFitQuest within two different school contexts.*

- *The development of a location-aware pervasive exergame, iFitQuest, as an example of how pervasive technology can be utilised for exergames for school-based physical activity interventions.*

A publication which provisionally covers many of the contributions within this thesis can be found at Macvean and Robertson [122]. This paper documents early findings based solely on the evaluation outlined in Chapter Seven.

- *Results from two prolonged use, school-based evaluations that highlighted the successful way pervasive exergames can be used to facilitate physical activity and minimise sedentary behaviour, as part of school-based exergame interventions, as well as providing an enjoyable and motivating experience for the players.* In particular, the successful way exergames can be integrated into differing school contexts, either as a replacement for, or in addition to, existing P.E. lessons, was highlighted.

- *Results from the aforementioned principal evaluations highlighted the variety of disparate in-game behaviours and experiences, and the way self-efficacy can be used to interpret and understand this behaviour.* In particular, the way goals are set, game selection habits, game difficulty preferences, and sources of attitude changes can all be explained when the self-efficacy of the participant is considered. Recommendations for the way self-efficacy can be utilised by future exergame practitioners is a primary contribution of this work.

- *Results on the importance of context, in particular the socio-ecological framework that underpins a context, and the influence this has on an exergame evaluation.* This highlights not only further consideration for exergame practitioners, but also highlights the need for real-world, in-situ evaluation of exergame systems for maximum validity.

10.2 Findings

The following findings add to the existing body of knowledge on exergames:

- The school children who participated in these evaluations were generally enthusiastic about the use of iFitQuest within their school. Participants found the experience both enjoyable and physically beneficial. For many, the game compared favourably with traditional P.E. lessons and sedentary class activities.

- This positive attitude towards exergames was mirrored by the participating teachers, who, like the children, agreed with the merits of exergames.

- While general success was observed across both of the primary empirical evaluations, the expert observers (P.E. teacher and learning assistant) commented that for those participants for whom iFitQuest was ineffective, or those children that had a negative exergame experience in terms of enjoyment and motivation, were generally those who had existing behavioural or attitude problems with respect to school and physical activity.

- Despite the above, iFitQuest appealed to gamers and non-gamers, participants from both genders, participants with a range of self-efficacies, fitness levels and attitudes towards exergames. Thus, while anecdotally attitude and behaviour may have been consistent with traditional P.E., iFitQuest was capable of appealing to a wide demographic.

- The possibility of a novelty effect within iFitQuest was highlighted in the second principal evaluation. When considering both principal evaluations, results suggest a novelty effect may begin to emerge around 6 weeks, replicating findings from other prolonged exergame evaluations and consistent with expected demotivation within traditional P.E. lessons.

- The influence of self-set goals on prolonged motivation and enjoyment within exergames was highlighted, in particular within the second principal evaluation.

- Throughout all iFitQuest evaluations (including later prototype evaluations), the blurred interpretation of what makes for a successful experience was highlighted. Some participants found success and enjoyment from earning points, winning mini-games, progressing through difficulty levels, and setting personal bests, while others favoured external factors like playing with friends and improving fitness. Different participants found enjoyment and motivation from different aspects of the system. Crucially, for many, success and enjoyment had no link, with participants still enjoying their experience despite not winning mini-games.

- Through flexible game design, exergames can support a variety of physical activity intensities, as well as supporting participants from a variety of backgrounds.

- Adopting a user-centred design approach for the design of exergames was found to be an effective way of balancing players' desires, contextual constraints and physical activity requirements. However, problems with regards to generating game content, as well as the influence of the social situation, were highlighted. According to Druin's work on the design of technology with children, the children worked best as *informants*, influencing design at various stages without being equal stakeholders in the design process [56].

10.3 Thesis Questions Revisited

This section relates the findings and contributions back to the main thesis research questions outlined in Chapter One.

10.3.1 RQ 1. To what extent can a location-aware exergame played within a school-based context promote physical activity, while remaining enjoyable and motivating?

At the most general level, the aim of this work was to design and build an effective exergame for an adolescent audience to be used within a school context. In order for the system to be effective, the game had to be enjoyable, physically demanding and motivating. A user-centred design process, combined with the iterative and prototype driven development cycle, was adopted in order to gather feedback from all user groups in an attempt to effectively meet the needs of the players, physical activity experts and contextual constraints of a school context.

iFitQuest was validated as an effective exergame, which was successfully integrated into two differing school contexts. The children who played the game generally found it to be enjoyable, motivating and physically demanding. The P.E. teacher, who observed the first principal evaluation, agreed that the system successfully facilitated the type of physical activity expected within a P.E. class, and that the children appeared to be well motivated and enjoyed the experience. Detailed evaluation of the log-files and accelerometer data showed that playing iFitQuest could contribute towards the player's physical activity targets while also reducing sedentary behaviour. As was discussed in Chapter Two, iFitQuest has the long term potential to positively influence the physical fitness of the participants, in particular when it is used in lieu of sedentary activities, as was the case in the second principal evaluation.

Anecdotally, in both studies, expert observers noted that those who had the more negative experiences with iFitQuest were generally those that were least enthusiastic towards traditional P.E., or school in general. Despite this, results showed that participants of all backgrounds could effectively utilise the iFitQuest system, in particular self-efficacy levels, starting fitness level, and gaming background appeared to play no role in the effectiveness of the system.

A potential novelty effect was observed in the second principal evaluation. As was outlined within Chapter Three and discussed within Chapter Eight, this type of novelty is not unexpected with respect to exergames and is generally expected for traditional school P.E. Further longitudinal evaluation is required to fully understand this phenomena within iFitQuest. Despite this, iFitQuest was effectively utilised over a prolonged period of use, and the length of time before a potential novelty effect was discovered outlines its potential to fit within a traditional school P.E. activity rota.

Finally, iFitQuest was effectively integrated into two disparate contexts, highlighting the potential of this genre, when carefully designed, to be utilised within a variety of school contexts. The contributed set of design guidelines can be adopted to aid in the design of an exergame for school use. Through the evaluation of iFitQuest, a number of logistical lessons were also learned, in particular with respect to designing for an adolescent audience, and evaluating a system within a school context. The influence of a school ecosystem was prevalent within both principal evaluations, reiterating the need to consider context when designing and evaluating an exergame system.

Location-aware exergames, when appropriately designed, can be effectively integrated into a school context. Additionally, they can provide a positive exergame experience, highlighting the potential of the genre to effectively target the physical activity issues prevalent with adolescent children. However, further work is required to generalise the results and fully understand the long term efficacy of the genre. Suggestions are provided within Chapter Nine for ways to effectively achieve this.

10.3.2 RQ 2. Which features and elements of iFitQuest contributed towards the exergame experience of the participants, and the overall success of the system?

In addition to the goal of creating an effective exergame, one purpose of the work within this thesis was to better understand the exergame experience. Building upon the work highlighted within Chapter Three, with exergames provisionally validated as a potentially effective medium for facilitating physical activity, it is important for practitioners to begin investigating in greater depth what is required for an effective exergame, and what elements contribute towards the experience of the player.

The two principal evaluations highlighted a number of aspects of the iFitQuest system which contributed effectively towards the experience of the players. The tension between collaboration and competition within a flexible system like iFitQuest highlighted different high-level sources of motivation, and the way two contrasting features can effectively be utilised in combination in order to contribute towards a motivating experience.

The way in which participants found motivation and enjoyment within a wide variety of micro- and macro-goals was emphasised within both principle evaluations. Of particular importance was the self-setting of goals, which can anecdotally be correlated with the overall success of the system. The design requirements adopted for iFitQuest highlight a number of key considerations when designing effective exergame experiences.

The evaluation of iFitQuest also highlighted the different interpretations of success within exergames. While some participants found success in winning the individual mini-games, or competing with their friends and class, others wanted to improve their fitness or simply enjoyed playing the mini-games. Crucially, an exergame should not impose too many constraints on the participants, otherwise the system runs the risk of alienating players, who would find optimal motivation and enjoyment elsewhere. Allowing for this variety, helps an exergame appeal to as wide a demographic as possible. Why people found success, enjoyment, and motivation from certain elements is the focus of further work, highlighted in Chapter Nine.

The context of an exergame evaluation was emphasised as playing an important role in the success of a system and the experience of the participants. Considering the context when designing and evaluating any exergame system is important for greater success as well as more valid results.

10.3.3 RQ 3. To what extent can self-efficacy be utilised to understand and explain the exergame experience?

As was highlighted within Chapter Two, the influence of self-efficacy on motivation, particularly within physical activity, is well validated and understood. Through a case study analysis, a number of interesting examples of the influence of self-efficacy within iFitQuest were identified. Self-efficacy was effectively used to understand and explain a number of disparate participant behaviours, across both of the primary empirical evaluations. The way participants set and altered goals, reacted to success and failure, customised difficulty levels, and selected which mini-game to play, were all influenced by the self-efficacy of the participants.

Within Chapter Eight, the implications of these findings for future exergame practitioners was discussed. Based on the findings of the iFitQuest evaluations, interpreting the results of an exergame evaluation through self-efficacy can effectively be used to explain the experience of the participants and provide insight into both the overall success of a system as well as the differing behaviours of the players. Crucially, the results of the iFitQuest evaluation highlight the potential to harness this understanding in order to create more effective exergame experiences in the future. With the potential to influence the attitude and motivation of the participant, self-efficacy could be effectively used to combat novelty effects and aid in the development of optimally effective exergames, more suited to targeting the health and fitness of the participants. Importantly, the influence of self-efficacy highlights the need for prolonged evaluation of a system. Various examples from the two principal evaluations showed the way behaviour and attitude change with time, and therefore the need for prolonged evaluation in order to fully understand the exergame experience.

With little exception, self-efficacy was effectively utilised to understand and explain the iFitQuest user experience. Within Chapter Eight, the implications for this on future exergame practitioners is outlined, while future work to further understand self-efficacy and its full potential within exergames is outlined in Chapter Nine.

10.4 Conclusion

This thesis investigated the effectiveness of a pervasive location-aware exergame as a means to promote physical activity for an adolescent demographic. Looking in greater depth than the general success of the game, self-efficacy was explored as a means to understand and explain the exergame experience, in particular, how self-efficacy affected attitude and motivation, and how this manifested itself in the behaviour of the exergame players. The results of two empirical evaluations highlighted the potential of exergames for this demographic and context. Evidence from the evaluation of iFitQuest also highlighted the prevalent effect of self-efficacy on the exergame experience, establishing it as an important consideration for future exergame practitioners wishing to evaluate existing exergames or when developing more effective exergames in the future. The evaluation also highlighted a number of key game features and design requirements which positively contributed towards the exergame experience.

Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.

Winston Churchill

APPENDIX A

Post-Evaluation Questionnaire

Exercise self-efficacy scale used in PASS

(from: www.nursing.umich.edu/faculty/penderinstrument/researchinstruments.html)

Below are some sentences about exercise.

Exercise means any sport or physical activity that makes your heart beat faster and makes you get out of breath some of the time.

Please tick ONE box for each sentence to show how true it is for you

	(1)	*(2)*	*(3)*	*(4)*
	Very true	Quite true	Not very true	Not at all true
I could exercise even if I was tired	☐	☐	☐	☐
I could exercise even if I had other things I wanted to do	☐	☐	☐	☐
I could exercise even if I had to exercise on my own	☐	☐	☐	☐
I could exercise even if I had a bad day at school	☐	☐	☐	☐
I could exercise even if I was feeling lazy	☐	☐	☐	☐
I could exercise even if I was not very good at it	☐	☐	☐	☐
I could exercise even if I was sore from exercising the day before	☐	☐	☐	☐
I could exercise even if I was not in the mood	☐	☐	☐	☐

Responses are reverse-coded so that very true=4 and not at all true=1. A mean score is computed by averaging responses to all eight items, range 1-4.

Self-Regulatory Efficacy

Pender's (Sample instruments, n.d.) *Self-Regulatory Efficacy* was comprised of eight statements, which measured the participant's commitment to exercise. For example, the participant would choose to exercise even if she were tired, if there were other things she wanted to do, or if she was having a bad day at school. Responses were coded as 0=not true at all to 4=very true. Overall self-regulatory efficacy was determined as the mean score across the eight items. Reliability data were moderate to strong for this instrument (test-retest=.77 and the Cronbach's alpha=.87) (Pender, Health promotion model: Psychometric properties, n.d.).

Pender, N. J.(n.d.). *Health promotion model: Psychometric properties of sample instruments*. Retrieved March 17, 2004 from http://www.nursing.umich.edu/faculty/pender/psychometric%20properties.pdf.

iPhone Exergames Post-Study Questionnaire

First of all, thank you very much for taking part in our study. We greatly appreciate the time you have sacrificed and the invaluable feedback you have provided.

Thank you also for taking the time to complete this questionnaire. Your feedback and suggestions are very important to us.

Please remember, we value all feedback, so please be honest when you answer the questions, do not just provide answers you think we want to hear. All your answers will be anonymised, and so cannot be tied back to you.

If you have any questions, please feel free to ask!

About you

1. **Your name** ______________________________
2. **How old are you?** I am ________ years old.
3. **What gender are you?**
   - ☐ Male
   - ☐ Female

Exercise Background

4. **Do you currently exercise / participate in sports outside school?**
   - ☐ Yes
   - ☐ No

If Yes;

5. **What sports / exercises do you currently play out of school hours?**
   - ☐ Football
   - ☐ Rugby
   - ☐ Dancing
   - ☐ Tennis
   - ☐ Squash
   - ☐ Basketball
   - ☐ Martial Arts
   - ☐ Running / Athletics
   - ☐ Gymnastics
   - ☐ Other (Please state): ______________________________

Please evaluate the following on a 10 point scale, where 1 low and 10 is high.

6a. **My Fitness** ____________

6b. **I Enjoy Exercising** ____________

6c. **I Enjoy My P.E. class** ____________

Exercise Video-Games

Please evaluate the following on a 10 point scale, where 1 low and 10 is high.

7a. **I enjoy playing exercise games** ____________

7b. **How much exercise do you feel you get when playing exercise game ?** ____________

iFitQuest

8. **Please Rate your overall Enjoyment of the iPhone exercise game study, giving a rating between 1 and 10**
   ____

9. **In general, how much Exercise do you believe you got whilst playing the game, giving a rating between 1 and 10, where 1 is no exercise (like sitting in class) and 10 is the maximum amount of exercise you could get in a given time**
   ____

10. **Overall, would you like to play the games again?** ☐ Yes ☐ No

11. **Please explain your answer.**
   ____
   ____

12. **Please rank the 5 games you played today in order of how much you Enjoyed them, place the numbers 1 - 6 beside each game where 1 is your favourite and 6 was your least favourite**
   Escape the Wolf ____
   Collect the Coins ____
   Follow the Chicken ____
   Return the Sheep ____
   Visit the Fields ____
   Mystery Game ____

13. **Please explain the reason for choosing your favourite game, why did you like it?**
   ____
   ____
   ____
   ____

14. **Please explain the reason for choosing your LEAST favourite game, why did you NOT like it?**
   ____
   ____
   ____
   ____

15. **In an average session, how did you choose which games to play?**
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____

16. **Did you ever manually INCREASE the difficulty?** ☐ Yes ☐ No

17. **Why?**
   ____
   ____
   ____
   ____

18. **Did you ever manually DECREASE the difficulty?** ☐ Yes ☐ No

19. Why?

____
____
____
____

Motivation

20. In general, please rate your overall levels of motivation with regards to playing the game, where 1 is no motivation (I just wanted to sit down) and 10 is maximum motivation (I was happy to run lots)

______

21. Please explain your answer, why did you choose that number?

____
____
____
____

22. Can you think of changes to the game which would have made you more motivated to play it.

____
____
____
____

23. Below are a few elements which may have motivated you to try hard when playing the game. Using a scale from 1 to 10 where 1 is no influence and 10 is maximum influence, please rate each element for how influential it was over your motivation levels when playing the game.

Trying hard to come top of the class leaderboard ____
Trying hard to beat your friends score ____
Trying hard simply to earn points ____
Trying hard to improve on your own mini-game scores (e.g. beating last weeks distance game score)____
Trying hard to earn more points than you had in previous weeks ____
Trying hard to win at the mini-games (i.e. satisfaction from escaping the wolf) ____
Trying hard as you simply enjoyed the games ____
Trying hard to improve your own fitness in general ____
Trying hard for the praise of the teacher ____

24. Is there anything, not included in the list above which motivated you to play the game?)

____
____
____

Final Thoughts

25. Can you think of any way to improve the games?

____
____
____
____
____

26. Do you have any final comments or suggestions?

Thank you once again for taking part in the study, and for taking the time to will in this questionnaire.

We hope that you enjoyed playing with the games, if not, you can still be satisfied that your playing of the game has provided some invaluable research.

If you have any final comments or suggestions, please feel free to email Andrew Macvean at: apm8@hw.ac.uk

HERIOT WATT UNIVERSITY

Health and Fitness Video-Game Usability Study

Your child is being asked to take part in a study looking at what makes for enjoyable and motivating exercise games. Your child will be asked to play a number of games designed as part of the project, and provide feedback on their experience.

Your child will be asked to fill in a pre-test questionnaire examining their attitudes towards video games and exercise, as well as a post-test questionnaire asking them for feedback on their experience of our games. Your child will also sit a pre- and post-test fitness assessment of appropriate level for this age group and carried out by a trained P.E. expert.

Please note that we will also ask your child's permission. If either you or your child does not wish the information to be stored or used we will not do so.

We also ask to video the group of children while playing the game, in order for us to further analyse their experience as well as to be used in promotional material (such as at academic conference).

All information gathered will be fully anonymised, stored securely and then destroyed once it has been used.

Child's name:

Parent or guardian's name:

- I agree for my child's data to be used in the iPhone Exergame project.

  ☐ Yes ☐ No

- I agree for my child to be video recorded whilst playing the game.

  ☐ Yes ☐ No

HERIOT WATT UNIVERSITY

Health and Fitness Video-Game Usability Study

Thank you for your interest in our 'iPhone Exercise Game Project' We hope that you enjoy playing our game and benefit from working with university researchers. We would like to use some of your information in our project as it will be useful when we come to developing our game further, as well as understanding what people of your age like about exercise games.

We would like to gather information from a questionnaire, as well as from a video recording of you playing our game.

Name:

I agree to take part in the iPhone Exercise Game Project.

☐ Yes ☐ No

APPENDIX B

Sample Field Notes

Sample field notes taken by Andrew Macvean and Judy Robertson from the high school evaluation (1st May 2012). Field notes appear in their original unedited form, although both separate researcher field notes have been integrated into a single document.

Notes from Visit to high school 1st May 2012

Present: Judy Robertson, Andrew Macvean, Sarah (Class P.E. Teacher).

Overview: Second session of the evaluation. After a successful pre-evaluation trial, and enthusiastic first session (17th April), the proposed second session (24th April) was cancelled due to adverse weather.

Conditions: 11 degrees, feels like 8 degrees according to Met Office, grass is wet underfoot. Not raining.

JR Field Notes: This week the girls are dressed more warmly for the weather in jackets or hoodies.

Some are not wearing appropriate footwear- little canvas shoes instead of trainers. AM encourages them to look at their statistics screen for points as he hands out the phones.

JR gives teacher a paper copy of the sorts of things she can do with the kids, and verbally reinforces them. From that point on, the teacher takes a much more active part in the class, explaining to one of the girls how it works, jogging between kids, asking them about points, comparing their points to other kids and encouraging them to run.

JR talks to some of the girls and gets to know them a bit. Lucy mentions to JR and teacher that she is stiff from athletics with cadets on Sunday. She did a 1500 m (4 mins), and 800m (2.27) and a 100m. She sits out for most of the lesson because there are not enough phones but she joins in just at the end and races Jessica round the track quite fast for about 200m. She is a good athlete when you see her running, and those times are good.

9.15am Isla has 21 points. JR encourages her to keep going.

Boy asks how to check leader board.

JR and teacher talk to Jack about points. He is very interested in them. He has 220. Teacher tells him Ross has more. Jack is worried that points from previous sessions have been lost so JR reassures him. He says sheep spawned outside fence and he had to wait for 54 seconds until the end of the game.

9.20 Lucy swaps in

Jack says "I've worked it out. Go slowly and you keep getting points faster". He complains he has now had the same mystery challenge 4 times in a row. AM explains mystery game selection is completely random.

Teacher encourages everyone to get as many points as possible in the last few minutes. She tells Daniel to run.

Lucy is frustrated because no points were recorded for her session.

This week Laura and Ava were sitting out. JR spoke to teacher about this. The teacher said that Laura has an ongoing issue with PE and she doesn't take part in any of it, and the guidance department have been involved. Ironically, at the start of the session, she was trudging round the warm up with another of the girls. The other girl said "I can't jog" and Laura said "Of course you can, everyone can jog", and gave her a pep talk. Of course, neither of them actually did the warm up.

The teacher said that she noticed those who worked hard at the game are the same people who take an active part in other PE activities such as basketball and those who dont try hard in the game dont try hard in PE either.

APM Field Notes:

9.10 - Males appear very motivated by the points. Ask researchers about prizes.

9.12 - Males quickly congregate to compare points (in particular Jack and Daniel).

Jack speaks to researchers and accuses Ross of cheating.

Daniel worried that his points are not being added correctly.

9.25 - It is observed that Sophie is playing the wrong game. She has exited the iFitQuest app and is playing one of the early prototypes of the mini-games which is still installed on the phone.

9.27 - Daniel is playing the game for first time. Appears to be really enjoying things. Plays game predominantly on his own, at far end of field. However, congregates with other boys to compare score.

9.30 - Emily and Sophie playing the games together. Never separate. Generally playing at a walking pace.

General Observations -

Game ran smoothly, with very few logistical problems.

Class were generally enthusiastic, in particular the boys who were highly motivated by points.

Lucy was tired from prior PA, but participated enthusiastically when she got the chance.

The teacher was positive about the class's enthusiasm and the amount of PA being done. She also appeared more enthusiastic herself. She was actively involved with encouraging the class.

APPENDIX C

Sample Log-File

Key	Type	Value
▼ Root	Dictionary	(39 items)
Log Number: 1	String	Time: 09:37:44 Message: Game Started
Log Number: 2	String	Time: 09:37:44 Message: Welcome
Log Number: 3	String	Time: 09:38:25 Message: Game: CHICKEN Outcome: WIN Points: 8 Time Played: 27 travelled: 10.19 at a speed: 0.84 level: 1
Log Number: 4	String	Time: 09:38:29 Message: Submitted Difficulty Level, old: 1 new: 2 custom change: 0
Log Number: 5	String	Time: 09:39:00 Message: Game: CHICKEN Outcome: WIN Points: 8 Time Played: 29 travelled: 28.17 at a speed: 2.17 level: 2
Log Number: 6	String	Time: 09:39:05 Message: Submitted Difficulty Level, old: 2 new: 3 custom change: 0
Log Number: 7	String	Time: 09:39:20 Message: Game: CHICKEN Outcome: LOSE Points: 4 Time Played: 9 travelled: 18.64 at a speed: 4.63 level: 3
Log Number: 8	String	Time: 09:39:32 Message: Message: Ratings Submitted Enjoyment: 3 Exertion: 4
Log Number: 9	String	Time: 09:40:10 Message: Game: AVERAGE Outcome: WIN Score: 6.60 Points: 10 Time Played: 30 travelled: 88.55 at a speed: 6.60
Log Number: 10	String	Time: 09:40:53 Message: Game: WOLF Outcome: WIN Points: 8 Time Played: 20 travelled: 74.57 at a speed: 8.34 level: 1
Log Number: 11	String	Time: 09:41:00 Message: Submitted Difficulty Level, old: 1 new: 2 custom change: 0
Log Number: 12	String	Time: 09:41:13 Message: Game: WOLF Outcome: LOSE Points: 4 Time Played: 9 travelled: 37.81 at a speed: 9.40 level: 2
Log Number: 13	String	Time: 09:41:17 Message: Submitted Difficulty Level, old: 2 new: 1 custom change: 0
Log Number: 14	String	Time: 09:41:26 Message: Game: WOLF Outcome: LOSE Points: 0 Time Played: 4 travelled: 0.95 at a speed: 0.53 level: 1
Log Number: 15	String	Time: 09:41:36 Message: Message: Ratings Submitted Enjoyment: 4 Exertion: 5
Log Number: 16	String	Time: 09:44:32 Message: Game: FIELD Outcome: LOSE Points: 5 Time Played: 171 travelled: 126.70 at a speed: 1.66 level: 1
Log Number: 17	String	Time: 09:44:42 Message: Message: Ratings Submitted Enjoyment: 1 Exertion: 2
Log Number: 18	String	Time: 09:45:06 Message: Game: SPEED Outcome: WIN Score: 13.23 Points: 10 Time Played: 20 travelled: 175.56 at a speed: 19.64
Log Number: 19	String	Time: 09:45:42 Message: Game: CHICKEN Outcome: LOSE Points: 4 Time Played: 14 travelled: 48.85 at a speed: 7.81 level: 2
Log Number: 20	String	Time: 09:45:54 Message: Message: Ratings Submitted Enjoyment: 2 Exertion: 4
Log Number: 21	String	Time: 09:46:31 Message: Game: COIN Outcome: WIN Points: 8 Time Played: 27 travelled: 37.09 at a speed: 3.07 level: 1
Log Number: 22	String	Time: 09:46:36 Message: Message: Ratings Submitted Enjoyment: 3 Exertion: 5
Log Number: 23	String	Time: 09:47:00 Message: Game: CHICKEN Outcome: LOSE Points: 2 Time Played: 15 travelled: 20.41 at a speed: 3.04 level: 1
Log Number: 24	String	Time: 09:47:11 Message: Message: Ratings Submitted Enjoyment: 3 Exertion: 5
Log Number: 25	String	Time: 09:48:04 Message: Game: DISTANCE Outcome: WIN Score: 130.04 Points: 10 Time Played: 40 travelled: 130.04 at a speed: 7.27
Log Number: 26	String	Time: 09:50:09 Message: Game: SHEEP Outcome: LOSE Points: 5 Time Played: 75 travelled: 72.99 at a speed: 2.18 level: 1
Log Number: 27	String	Time: 09:50:17 Message: Message: Ratings Submitted Enjoyment: 4 Exertion: 4
Log Number: 28	String	Time: 09:50:48 Message: Game: CHICKEN Outcome: LOSE Points: 4 Time Played: 17 travelled: 48.23 at a speed: 6.35 level: 1
Log Number: 29	String	Time: 09:51:01 Message: Message: Ratings Submitted Enjoyment: 3 Exertion: 6
Log Number: 30	String	Time: 09:51:40 Message: Game: WOLF Outcome: WIN Points: 7 Time Played: 20 travelled: 64.71 at a speed: 7.24 level: 1
Log Number: 31	String	Time: 09:51:58 Message: Message: Ratings Submitted Enjoyment: 4 Exertion: 5
Log Number: 32	String	Time: 09:52:46 Message: Game: DISTANCE Outcome: LOSE Score: 70.27 Points: 1 Time Played: 40 travelled: 70.27 at a speed: 3.93
Log Number: 33	String	Time: 09:53:15 Message: Game: CHICKEN Outcome: LOSE Points: 4 Time Played: 12 travelled: 34.56 at a speed: 6.44 level: 1
Log Number: 34	String	Time: 09:53:22 Message: Message: Ratings Submitted Enjoyment: 5 Exertion: 4
Log Number: 35	String	Time: 09:54:17 Message: Game: CHICKEN Outcome: LOSE Points: 2 Time Played: 12 travelled: 25.54 at a speed: 4.76 level: 1
Log Number: 36	String	Time: 09:54:35 Message: Message: Ratings Submitted Enjoyment: 9 Exertion: 3
Log Number: 37	String	Time: 09:54:54 Message: Message: Session Totals Distance: 1186.16 Avg Speed: 2.58 Total Time:1029
Log Number: 38	String	Time: 09:54:54 Message: Game Quit
key1	String	value1

Figure C.1: Sample of log-file produced by iFitQuest.

APPENDIX D

Sample Weekly Data Summary

Participant Category	Total Dist	Total Time	Games Played	Total Points	Wolf							
					Plays	Wins	Loses	Dist	Time	Avg Speed	Points	Highest Lvl
David	2151.52	16 mins 28	13	89	1	1	0	94.32	20	10.55	8	1
Ben	1183.26	31 mins 55	11	70	0	0	0	0	0	0	0	0
Nick	277.31	6 mins 50	5	29	1	1	0	44.09	20	4.93	8	1
Holly	1465.13	23 mins 6	14	89	1	0	1	80.35	19	9.46	5	1
Hannah	1296.93	24 mins 16	20	116	2	0	2	5.77	9	1.43	0	1
Anna	1089.59	14 mins 22	8	59	0	0	0	0	0	0	0	0
Abigail	548.98	17 mins 37	6	48	0	0	0	0	0	0	0	0
Alice	1182.42	14 mins 12	13	73	5	1	4	108.46	41	5.89	16	1
Olivia	467.70	7 mins 51	5	35	0	0	0	0	0	0	0	0
Jennifer	1729.05	24 mins 16	24	136	9	4	5	415.53	195	4.76	42	2
Mia	1374.47	10 mins 37	22	127	6	4	2	414.17	117	7.92	33	3

*All swapped phones

Participant Category	Chicken								Field							
	Plays	Wins	Loses	Dist	Time	Avg Speed	Points	Highest Lvl	Plays	Wins	Loses	Dist	Time	Avg Speed	Points	Highest Lvl
David	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Ben	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nick	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holly	1	1	0	25.05	27	2.08	8	1	1	0	1	165.24	171	2.16	5	1
Hannah	0	0	0	0	0	0	0	1	1	1	0	122.38	118	2.31	7	1
Anna	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abigail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alice	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Olivia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jennifer	1	0	1	8.37	9	2.08	5	1	0	0	0	0	0	0	0	0
Mia	2	0	2	60.17	27	4.98	9	1	2	1	1	313.72	241	2.91	12	1

Participant Category	Coin								Sheep							
	Plays	Wins	Loses	Dist	Time	Avg Speed	Points	Highest Lvl	Plays	Wins	Loses	Dist	Time	Avg Speed	Points	Highest Lvl
David	9	5	4	459.63	366	2.81	53	9	0	0	0	0	0	0	0	1
Ben	9	5	4	460.69	606	1.70	50	5	0	0	0	0	0	0	0	0
Nick	2	1	1	138.51	148	2.10	13	2	0	0	0	0	0	0	0	0
Holly	6	4	2	274.62	289	2.13	35	4	1	0	1	90.76	75	2.71	5	1
Hannah	10	10	0	311.14	324	2.15	70	8	2	0	2	192.31	246	1.75	9	1
Anna	5	4	1	277.49	226	2.74	34	4	1	0	1	75.17	75	2.24	5	1
Abigail	3	2	1	120.13	170	1.58	20	3	0	0	0	0	0	0	0	0
Alice	1	1	0	35.75	27	2.96	8	1	2	0	2	118.41	150	1.76	7	1
Olivia	2	0	2	186.05	232	1.79	10	1	1	0	1	76.68	75	2.29	5	1
Jennifer	7	6	1	347.49	247	3.14	43	7	1	0	1	157.07	75	4.68	5	1
Mia	6	6	0	196.94	112	3.93	42	6	0	0	0	0	0	0	0	0

Participant Category	Dist							Avg Speed						
	Plays	Wins	Loses	Dist	Time	Avg Speed	Points	Plays	Wins	Loses	Dist	Time	Avg Speed	Points
David	2	2	0	261.23	80	7.3	18	1	1	0	109.51	30	8.17	10
Ben	1	1	0	30.89	40	1.73	10	0	0	0	0	0	0	0
Nick	1	1	0	25.67	40	1.44	10	0	0	0	0	0	0	0
Holly	2	1	0	241.81	80	6.77	11	1	1	0	193.44	30	14.43	10
Hannah	1	1	0	108.34	40	6.06	10	2	2	0	182.46	60	6.79	20
Anna	1	1	0	148.79	40	8.32	10	1	1	0	104.08	30	7.76	10
Abigail	0	0	0	0	0	0	0	3	3	0	266.48	90	6.61	28
Alice	3	2	1	294.43	120	5.48	22	1	1	0	99.62	30	7.43	10
Olivia	1	1	0	154.84	40	8.66	10	0	0	0	0	0	0	0
Jennifer	2	2	0	228.05	80	6.38	20	2	2	0	107.8	30	8.05	10
Mia	2	1	1	230.32	80	6.43	11	2	2	0	97.59	30	7.23	10

Participant Category	Top Speed						
	Plays	Wins	Loses	Dist	Time	Avg Speed	Points
David	0	0	0	0	0	0	0
Ben	1	1	0	6.85	20	0.77	10
Nick	1	1	0	0	20	0	0
Holly	0	0	0	0	0	0	0
Hannah	1	0	1	0	0	0	0
Anna	0	0	0	0	0	0	0
Abigail	0	0	0	0	0	0	0
Alice	1	1	0	63.94	20	7.15	10
Olivia	1	1	0	14.55	20	1.63	10
Jennifer	2	1	1	107.58	40	6.04	11
Mia	2	1	1	61.56	20	6.88	10

APPENDIX E

Focus Group Results

Within this appendix, additional results from the two requirements gathering focus groups are presented. As the aims, objectives, and findings have all been discussed within the main text of this thesis, results are presented without commentary.

E.1 Focus Group 1: Content Requirements Gathering

- All 6 pupils played video games.
- All 3 males were regular game players.
- One female regularly played games.
- Two females were 'casual' gamers.
- All six participants played games on their mobile devices.
- One person regularly played exergames.
- Remaining five participants had no intention of playing exergames.

Exercise 1: What is your favourite game and why? - Roundtable discussion

- Easy to just pick up and play. Good for passing the time when bored.
- Like first person shooters. 70% - 90% of the time play multiplayer mode as like playing against friends. Like the customisation, freedom to pick guns, etc. Also like the pointless creative freedom such as designing on clan tags which have no real bearing on the game.
- Like the fact it is both a single player and co-op. Like the puzzles and the fact that it is something different. Like the fact it doesn't need to be all about guns.
- Fun to play with friends; easy to pick up and play.

- Like the multiplayer. Was not exactly sure why she played it.
- Puzzle solving, easy to pick up and play. Passes the time.
- Like the intelligence aspects. Liked the fact that it could help with intelligence. Liked the puzzles.
- Like the story.
- Like that I have lots of freedom to explore like I want.

Exercise 2: What do you look for when choosing which video game to play? - Roundtable discussion

- Likes when a game contains something different; there are too many clichéd and similar games, and so, when something which has never been done before comes out, it is instantly appealing.
- The 4 regular gamers agreed - Creative freedom is a must. None liked playing games where they felt they had no real choices, no matter how well implemented other aspects were.
- However, it is essential that there is an overall goal. There was a strong dislike to open ended games (Farmville, The Sims etc.).
- Like games which mirror real world interests i.e. gaming female admitted to liking racing games, as she really likes cars.
- Overriding goal, but freedom to complete that goal in whatever way we wish.
- "I need a reason to play the game".
- Like it when progress is reflected with upgrades.

Exercise 3: What game elements are most important to you when playing a game? - Individual card sort

Figure E.1 shows the final sorted cards for each of the four participants who participated. Note, two people were unable to complete the exercise as they felt they had insufficient knowledge.

Using a coding scheme, each mechanic was awarded points based on how it was sorted by each participant. Figure E.2 shows the total points for each game element.

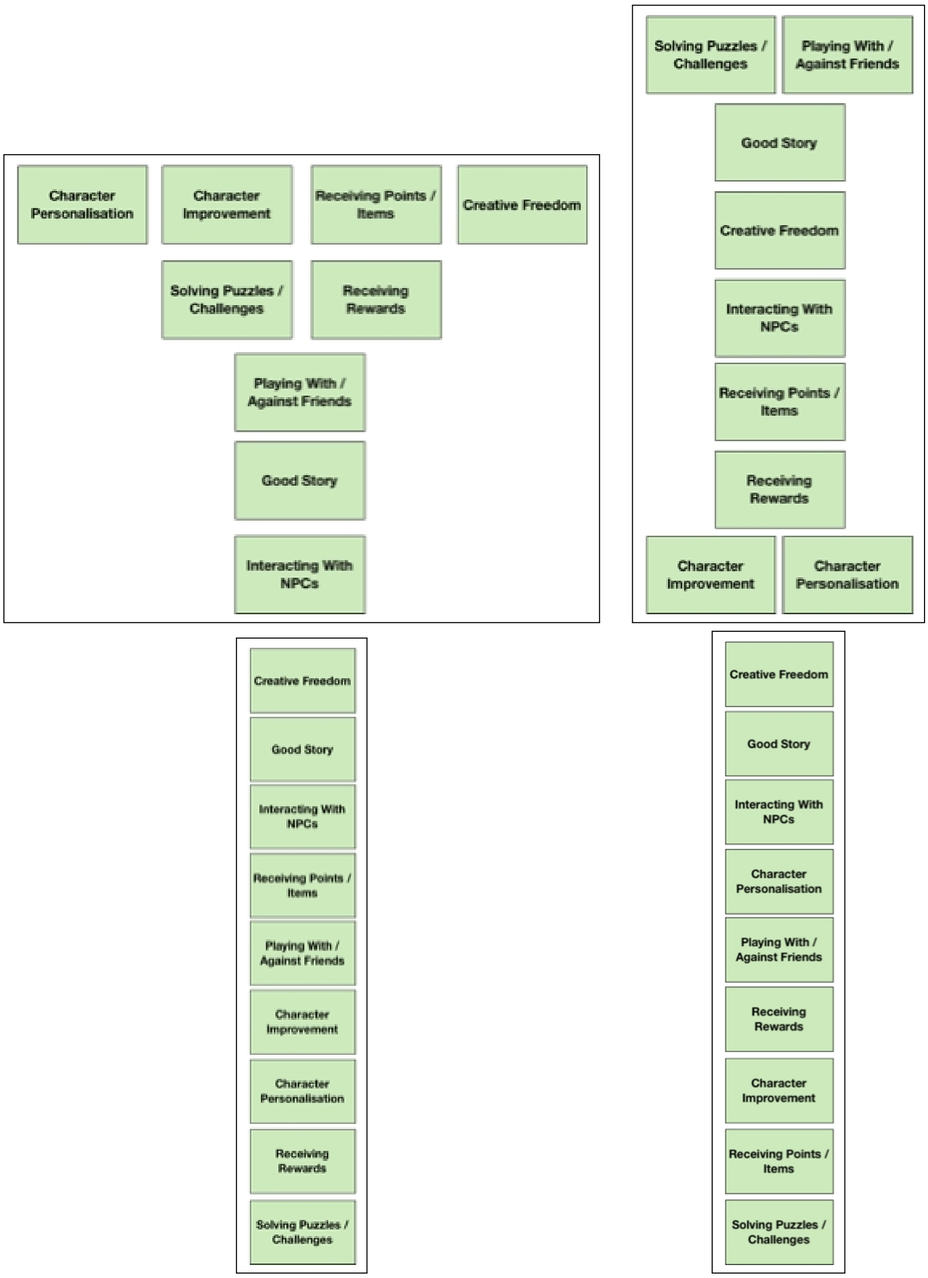

Figure E.1: Results of the game mechanic card sort.

Exercise 4: What game elements do you particularly dislike? - Roundtable discussion

- When a game is “pointless”.
- When games are too complicated.
- “When I do not know how to play”.
- When a game is too different from my interests.
- When a game had no finishing point.

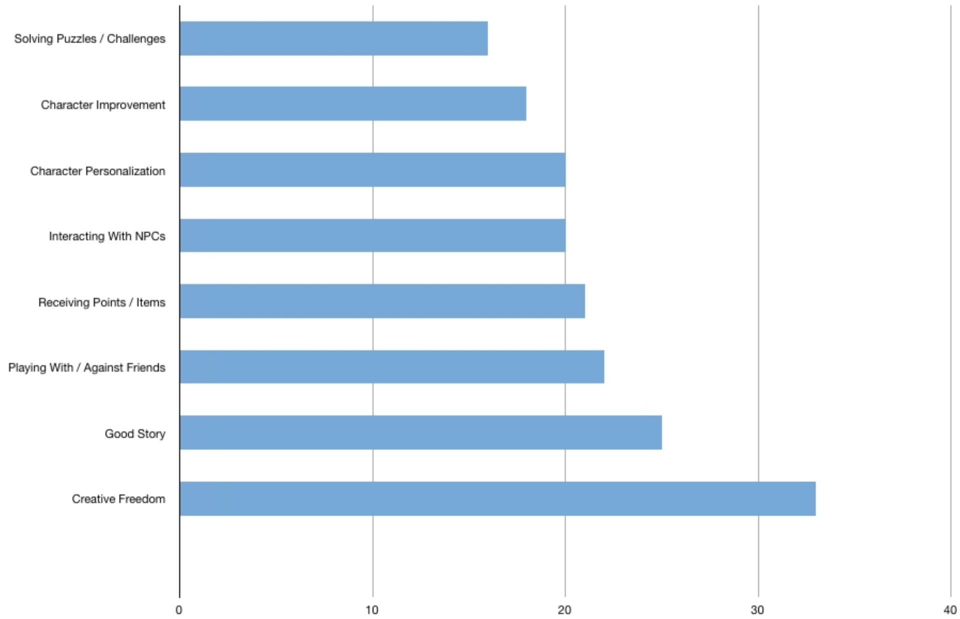

Figure E.2: Final card sorting points.

- "Games when there is no feedback. It is important to know that I am doing is right".

Exercise 5: Exergame discussion - Roundtable discussion

- One participant regularly played them as their primary form of exercise.
- Regular player found them enjoyable and motivating.
- Other players had no current interest in exergames.
- One participant felt they didn't actually encourage you to exercise.
- One participant felt they were too easy to cheat at.
- All participants felt that if you were not already motivated to exercise, you wouldn't exercise in an exergame.
- All participants liked the idea of a real world game, as it would be difficult to cheat and be easier to play with friends.

Exercise 6: Exergame design - Group brainstorming exercise

The final phase of the focus group was a brainstorming exercise for exergame designs. While the participants were capable of identifying game elements they did and did not like, they were unable to come up with any ideas of their own. Two participants complained that it was impossible, as they had never played an exergame.

It was decided that this exercise should be posponed, and participants should be able to trial exergames at a later date before continuing the design process.

E.2 Focus Group 2: Exergame Playthrough

The same six participants from the initial focus group were selected to participate in this focus group. Therefore, the background information is consistent with that shown in Section E.1. The following field notes were made by Judy Robertson and Andrew Macvean on the day of the focus group. Pseudonyms have been used to protect anonymity.

Judy Robertson Field Notes

The purpose of the session was to observe 6 3rd year pupils use Wii fitness games and get their opinions about them. There were 3 boys and 3 girls who worked with Andy the previous week. Their computing teacher, Susan Burns, was present. The session lasted for 40 minutes and took place in the computing classroom. We spent about 20 minutes on the Wii Fit. Jack volunteered to try it before seeing what it involved. (Only Mary had played it before). It took quite a while to set up a Mii and to do initial tests before starting to play a game. The kids know what BMI is. Mary would not like to make her BMI public, although she did not mind playing in front of the others, or helping with the equipment. Stephanie exclaimed that the centre of gravity test was "cool". Jack thought the robot voice used by the Wii board itself was "creepy". Jack was confused by the athletic ability test initially but got it quite quickly. It is quite a dull spectator sport because the user doesn't move much and there isn't much to see on screen. Jack Wii age is the same as his own age. The Wii Fit prompts for goal setting (target weight in a time period) but does not suggest what would be a sensible goal or suggest how the user should work out a goal. The onscreen trainer: "That was a tough workout" Jack : "Yeah" (sarcasm) Stephanie was adamant that she would not use the wii fit in front of people because it would be embarrassing. When I asked the kids what they thought of it after Jack had finished they said:

- It would be better to have a real environment like a gym to make it more realistic.
- It would be better to have clearer explanations of the actions to do.
- Takes too long to set up.

- Didn't do it for long enough to feel tired.

Another boy then tried a balancing game in which you have to get a ball into a hole. Again, Stephanie spontaneously said "that's so cool". I asked the children what they thought of the trainer:

- Annoying voice and accent.
- Patronising.
- He repeated himself.
- should be able to change his appearance (he is portrayed as a mirror image of yourself, after all).

The third boy then played a header game. Again, he did not find it tiring. Mary then played the step game by herself. Fiona was laughing and enjoying Mary playing the step game. I asked the girls which was more embarrassing: playing the wii fit or doing PE. They said that the Wii fit was because people were watching you whereas in PE everyone was doing it together. They said they would play it at home by themselves. In fact Mary does this. She plays it with her mum. They have had a wii fit for about a year and use it at evenings and weekends. They use it for weight. We gave the kids the choice of what game to play next: Beach games or Dance. The boys plus Fiona vote for the beach games. The girls still don't want to play so Jack plus another boy start with football. This is not remotely fitness related because they don't have to move. The girls decide they will play together on the next one (Stephanie and Fiona). They choose Water Rocket. Stephanie says "I'm so proud of you" to Fiona. The boys have some trouble playing the football game but do not get ridiculed or instructed by the other kids from the sideline. Stephanie says "that's so cool" at some effects during the game. She also says "I think we can do it Taylor" after the teacher points out they can hardly do worse than the boys. Previously I heard Stephanie say to Jack "Every day of my life you make me feel bad about myself". When the girls start playing, Fiona says she doesn't want to play with a boy avatar. Jack reads the instructions on screen, and then advises Fiona on them. She wants to know how he knows did she miss them? Jack says "this is going to be good" in sarcasm before they start. The boys offer a lot of advice to the girls, and some insults, general running commentary This is the first time anyone has done this. Is it because the girls' performance is bad? Is it because they made a fuss about doing it at all? Jack is patronising "It's like a steering wheel, OK, Fiona?" In spite of the negative commentary the girls seem to be enjoying it and they laugh as they play. As the bell rings, they say "oh no". General observations:

- Stephanie and Fiona started off with saying they only liked Tetris, but then volunteered excited comments about the games as they watched. They also seemed to like playing it.
- S&F were very reluctant to play the game with people watching. This proved to be justified because they did get more commentary from the boys than the others. This seemed to be a vicious cycle they made a big deal of it, so people made a big deal of them taking part. In contrast people did not comment on Mary playing. She was good at it.
- The games were not useful from a fitness point of view. We need something which gets them exercising almost immediately, and something where they can merge into a class rather than be isolated with spectators. Would it be worth considering a 2 player version where the girls can work with each other?

Andrew Macvean Field Notes

Player 1 The first volunteer was the keen game developer and gamer from session 1. He was happy to step up first and exercise in front of the class despite having no prior experience with the Wii Fit. He chose to do a muscle workout, this contained very little game mechanisms but was more akin to a tutorial. P1 had to follow an onscreen trainer who demonstrated a number of stretches. At the end of the workout P1 was awarded points and a star rating based on his distribution of weight on the Wii balance board.

P1 felt that the actions were not clearly explained and was therefore confused while performing the workout. He felt that he did not receive a workout as the activity was not very intense. P1 did not like the setting of the activity (a basic white room with a generic personal trainer), they would have preferred if they were performing the action as part of a) a more realistic environment (the gym) or b) as part of a mini game.

Player 2 Participant 2 was the non sporty puzzle gamer. Like P1, P2 had never played any H&F games and had no real desire to. P2 chose to play a balance game in which they were required to shift their weight on the balance board in order to tilt a table , steering balls towards holes

P2 did not feel tired, despite playing for over 5 minutes. The workout was of a very low intensity. Despite being one of the most adamant non-exergamers, P2 admitted he was surprised by how enjoyable the experience was. It was not at all what they had expected and having played the game, they admitted they would be happy to play the Wii Fit again. P2 like the progression of difficulty and was motivated to play the game again to see if he could reach a further level.

Player 3 Participant 3 also chose to play one of the balance activities, opting for a football game as this is his real world sport of choice.

Again, P3 did not feel in the least bit tired, however having chosen to do a balance activity this is to be expected. Like P2, P3 was surprised by the type of game available and found the game a lot more enjoyable than they expected.

Player 4 Participant 4 was the only one in the focus group who had previously used the Wii Fit. She classed herself as a regular user and thought of it as a fun alternative to traditional exercise.

She chose to do an aerobic workout, using the Wii board in order to simulate a step class. P4 admitted she definitely felt she had just had a workout although she would not class herself as tired. She liked the fact that good performance would unlock more advance step classes which would include new moves for you to try, keeping the game novel and interesting. She was thus motivated to play again as she wanted to see the new moves. She also felt that the points system and star rating were important aspects of the game as they allowed her to monitor her performance and compare it to previous sessions. She did not actually know what purpose the points served.

Player 5&6 Girls would only play as a team.

Despite having reservations about a) video games in general and b) playing in front of an audience, P5 and P6 immediately appeared to enjoy the experience. They were keen to select an appropriate game character I dont want to be a boy showing the importance of image in the game. They chose not to read the instructions and this lead to instant confusion during play. This correlates with what they said in FG1 in which they said games needed to be easy to pick up and play and that they were put off by games with complex controls.

Although they did not feel fully at ease in front of the class, they were disappointed when the bell went signalling an end to the session.

Notes Social Context - Carefully consider the social situation. There were examples of name calling, while the females were self-conscious about PA in-front of their peers.

Intensity Level - too low for a short session. Games must be designed so as to very quickly facilitate more PA. Points System - Was a good motivator and a method to monitor progress and performance. Level Progression - Unlocking new levels and moving through difficulties was a positive motivator. Need a smooth learning curve so that players do not face difficulty challenges too soon. Enjoyment - Even those with serious reservations enjoyed the experience highlighting the potential of exergames.

APPENDIX F

Post-Evaluation Interview Questions

The following list contains the general skeleton of post-evaluation interview questions. Although this overall structure was followed, additional questions were also asked where appropriate to clarify or expand upon a point made by the participant. Additional questions were also posed to those participants that observations / log-file analysis highlighted as having unique behaviour.

In-Game Habits

1. Did you feel like you had a tactic while playing the game / an approach that you followed when deciding which mini-game to play?
2. Did you feel like your tactic / approach changed over the course of the evaluation?
3. If so, why? / What influenced you in changing your tactics?
4. The log-files from your gameplay suggest that you moved from tactic x to tactic y, would you agree with this?
5. Log-files showed that you regularly made the game harder / easier. Can you explain why you did this?
6. Log-files showed that you predominantly played Game x. Can you explain the reason why?
7. When you started a new session, how did you decide which game to play first?

Motivation

1. Generally, how motivated to exercise did you feel whilst playing iFitQuest?
2. Would you say your level of motivation changed over the course of the evaluation?

3. If so, why?
4. You appeared one of the most / least motivated members of the class. Would you say this is accurate?
5. If so, why?
6. Can you give me a reason why you tried so hard / didn't want to try?
7. You played the game for x weeks. Can you imagine playing the game for longer?
8. If yes, how many more weeks?
9. If no, how long would be the ideal length for you?
10. Would you say you had a particular goal whilst playing the game?
11. Why did you adopt that particular goal?
12. How did you react when you did / did not reach your goal in a session?

Attitude

1. In the questionnaire, you rated your enjoyment of the experience as x. Can you explain why you rated it at this level?
2. What aspects of the game influenced your level of enjoyment?
3. Some people have commented that it did not matter to them whether they won or lost a game. Would you say this is accurate for you?
4. Did you prefer your traditional P.E. class or iFitQuest?
5. Would you like to see iFitQuest incorporated as part of your traditional P.E. class?
6. Which of the mini-games were your favourite?
7. Why did you like that game the most?
8. How did you feel when you met your goal?

APPENDIX G

Research Question Schema

This appendix outlines in greater depth the hierarchy of research questions investigated during this thesis. While three primary research questions are outlined within Chapter One, these questions are broken down into a number of relevant sub-questions within the two principal evaluations outlined in Chapter Six and Chapter Seven. A visual representation of how each sub-question relates to the three principal research question is provided.

In addition to this, Table G.1 outlines the approaches taken to answer each question. With a mixed methods methodology adopted for the evaluations, Table G.1 serves to consolidate which sources of data and data analysis techniques were used to answer each of the key sub-questions which formed the basis of investigation within this thesis.

This section requires two important notes. First, not all of the key discussions which take place within Chapter Eight are captured within these research questions and sub-questions. Emergent themes and interesting discussion points arose during the two principal evaluations. Thus, while this schema serves to highlight how the sub-questions outlined in Chapter Six and Chapter Seven relate to the three main research questions, the schema does not represent an exhaustive list of all discussion points which occur within this thesis. Secondly, due to the mixed methods analysis, and overlap between sub research questions, it is not possible to create a completely valid mapping between data source, sub-question, and main question. In many cases, sub-questions contributed knowledge towards multiple primary research questions. Likewise, the case study analysis contributed towards many of the sub-questions. Therefore, while the data within Table G.1 is as accurate as possible, it is important to consult the main body of text within the thesis to understand exactly how contributions were drawn on a particular topic, especially when multiple data sources were consulted to reach an answer.

- RQ 1. To what extent can a location-aware exergame played within a school-based context promote physical activity, while remaining enjoyable and motivating?
  - RQ 6.1 – Is iFitQuest enjoyable to play?
  - RQ 6.2 – Is iFitQuest physically demanding?
    RQ 6.2 (a) – Can iFitQuest facilitate prolonged PA?
    RQ 6.2 (b) – Can iFitQuest facilitate a range of PA intensities?
  - RQ 6.3 – Is there a novelty effect within the iFitQuest system?
  - RQ 7.1 – Is iFitQuest enjoyable to play?
  - RQ 7.2 – Is iFitQuest physically demanding?
    RQ 7.2 (a) – Can iFitQuest facilitate prolonged PA?
    RQ 7.2 (b) – Can iFitQuest facilitate a range of PA intensities?
    RQ 7.2 (c) – Can iFitQuest improve the fitness level of the participants?
  - RQ 7.3 – Is there a novelty effect within the iFitQuest system?
  - RQ 7.10 – Is iFitQuest appealing to a younger demographic?
- RQ 2. Which features and elements of iFitQuest contributed towards the exergame experience of the participants, and the overall success of the system?
  - RQ 6.4 – What is there to learn about the exergame experience through prolonged play?
    RQ 6.4 (c) – How does gender affect the participants' experience?
    RQ 6.4 (d) – What can be learned about players' in-game motivation?
  - RQ 6.3 – How does iFitQuest fit within the school context for a prolonged intervention?
  - RQ 7.4 – What is there to learn about the exergame experience through prolonged play?
    RQ 7.4 (c) – What can be learned about players' in-game motivation?
  - RQ 7.9 – How does the primary school context affect the experience?
  - RQ 7.11 – Do the design requirements of the iFitQuest system fit within the primary school context?
- RQ 3. To what extent can self-efficacy be utilised to understand and explain the exergame experience?
  - RQ 6.4 – What is there to learn about the exergame experience through prolonged play?
    RQ 6.4 (a) – Does player behaviour change with time?
    RQ 6.4 (b) – How does the self-efficacy of the participant affect their experience?
    RQ 6.4 (d) – What can be learned about players' in-game motivation?
  - RQ 7.4 – What is there to learn about the exergame experience through prolonged play?
    RQ 7.4 (a) – Does player behaviour change with time?
    RQ 7.4 (b) – How does the self-efficacy of the participant affect their experience?
  - RQ 7.5 – How does the self-efficacy of the participant affect their mini-game selection habits?
    RQ 7.5 (a) – How does the self-efficacy of the participant influence replay or avoid behaviour?
    RQ 7.5 (b) – How does the self-efficacy of the participant influence their difficulty level setting?
  - RQ 7.6 – How does the self-efficacy of the participant affect their goal setting?
  - RQ 7.7 – How does the self-efficacy of the participant affect their goal-commitment?
  - RQ 7.8 – How does the self-efficacy of the participant affect their reaction to success or failure?

Table G.1: Research questions with a description of the associated data types and analysis utilised to answer the questions.

Research Question	Data Types	Data Sources	Data Analysis
6.1 Is iFitQuest enjoyable to play?	Qual. & Quant.	1. Post-evaluation questionnaire. 2. Post-evaluation interview. 3. Researcher observation.	1. Self-reported enjoyment descriptives. 2. Inductive content analysis of interviews and observation field notes.
6.2 Is iFitQuest physically demanding?	Qual. & Quant.	1. Log-files. 2. Expert observation. 3. Post-evaluation questionnaire.	1. Self-reported exertion descriptives. 2. Log-file analysis. 3. Content analysis of expert interview notes.
6.2 (a) Can iFitQuest facilitate prolonged PA?	Quant.	1. Log-files.	1. Frequency of MVPA change by week.
6.2 (b) Can iFitQuest facilitate a range of PA intensities?	Quant.	1. Log-files.	1. mph estimation method for MVPA calculation.
6.3 Is there a novelty effect within the iFitQuest system?	Qual. & Quant.	1. Log-files. 2. Post-evaluation questionnaire.	1. Replay game descriptives. 2. ANOVA on player distance by week (Bonferroni post-hoc). 3. Frequency of MVPA change by week.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
6.4 What is there to learn about the exergame experience through prolonged play?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation. 3. Expert observation. 4. Post-evaluation interview.	1. Wilcoxon Signed-Rank on Pre- and post-evaluation self-reported attitude descriptives. 2. Case study analysis. 3. Inductive content analysis of interviews and observation field notes. 4. Mixed methods convergent analysis across data sources.
6.4 (a) Does player behaviour change with time?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation. 3. Expert observation. 4. Post-evaluation interview.	1. Wilcoxon Signed-Rank on Pre- and post-evaluation self-reported attitude descriptives. 2. Case study analysis. 3. Inductive content analysis of interviews and observation field notes.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
6.4 (b) How does the self-efficacy of the participant affect their experience?	Qual. & Quant.	1. Pre- and post-evaluation self-efficacy questionnaire. 2. Researcher observation. 3. Expert observation. 4. Post-evaluation interview.	1. Paired samples t-test (2-tailed) on pre- and post-evaluation self-efficacy scores. 2. Case study analysis. 3. Inductive content analysis of interviews and observation field notes.
6.4 (c) How does gender affect the participants experience?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation.	1. Mann-Whitney U on self-reported enjoyment by gender. 2. Inductive content analysis of interviews and observation field notes.
6.4 (d) What can be learned about players in-game motivation?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation. 3. Post-evaluation interviews.	1. Case study analysis. 2. Inductive content analysis of interviews and observation field notes.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
6.5 How does iFitQuest fit within the school context for a prolonged intervention?	Qual.	1. Researcher observation. 2. Expert observation. 3. Pre- and post-evaluation questionnaire. 4. Post-evaluation interviews.	1. Inductive content analysis of interviews and observation field notes. 2. Mixed methods convergent analysis across data sources. 3. Case study analysis.
7.1 Is iFitQuest enjoyable to play?	Qual. & Quant.	1. Post-evaluation questionnaire. 2. Post-evaluation interview. 3. Researcher observation.	1. Self-reported enjoyment descriptives. 2. Inductive content analysis of interviews and observation field notes.
7.2 Is iFitQuest physically demanding?	Qual. & Quant.	1. Log-files. 2. Expert observation. 3. Post-evaluation questionnaire. 4. Accelerometer.	1. Self-reported exertion descriptives. 2. Log-file analysis. 3. content analysis of expert interview notes. 4. Accelerometer MVPA data analysis.
7.2 (a) Can iFitQuest facilitate prolonged PA?	Quant.	1. Log-files.	1. Frequency of MVPA change by week.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
7.2 (b) Can iFitQuest facilitate a range of PA intensities?	Quant.	1. Log-files. 2. Accelerometer.	1. mph estimation method for MVPA calculation. 2. Accelerometer MVPA data analysis.
7.2 (c) Can iFitQuest improve the fitness level of the participants?	Quant.	1. Pre- and post-evaluation Bleep Test.	1. T-test on pre- and post-evaluation Bleep Test scores.
7.3 Is there a novelty effect within the iFitQuest system?	Qual. & Quant.	1. Log-files. 2. Post-evaluation questionnaire.	1. Replay game descriptives. 2. Frequency of MVPA change by week.
7.4 What is there to learn about the exergame experience through prolonged play?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation. 3. Expert observation. 4. Post-evaluation interview.	1. Wilcoxon Signed-Rank on Pre- and post-evaluation self-reported attitude descriptives. 2. Case study analysis. 3. Inductive content analysis of interviews and observation field notes. 4. Mixed methods convergent analysis across data sources.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
7.4 (a) Does player behaviour change with time?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation. 3. Expert observation. 4. Post-evaluation interview.	1. Wilcoxon Signed-Rank on Pre- and post-evaluation self-reported attitude descriptives. 2. Case study analysis. 3. Inductive content analysis of interviews and observation field notes.
7.4 (b) How does the self-efficacy of the participant affect their experience?	Qual. & Quant.	1. Pre- and post-evaluation self-efficacy questionnaire. 2. Researcher observation. 3. Expert observation. 4. Post-evaluation interview.	1. Paired samples t-test (2-tailed) pre- and post-evaluation self-efficacy scores. 2. Case study analysis. 3. Inductive content analysis of interviews and observation field notes.
7.4 (c) What can be learned about players in-game motivation?	Qual. & Quant.	1. Pre- and post-evaluation questionnaire. 2. Researcher observation. 3. Post-evaluation interviews.	1. Case study analysis. 2. Inductive content analysis of interviews and observation field notes.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
7.5 How does the self-efficacy of the participant affect their mini-game selection habits?	Qual. & Quant.	1. Log-files. 2. Researcher observation. 3. Post-evaluation interviews. 4. Pre- and post-evaluation self-efficacy questionnaire. 5. Post-evaluation questionnaire.	1. Case study analysis. 2. Inductive content analysis of interviews, questionnaire responses, and observation field notes. 3. Mixed methods convergent analysis across data sources.
7.5 (a) How does the self-efficacy of the participant influence replay or avoid behaviour?	Qual. & Quant.	1. Log-files. 2. Post-evaluation interviews. 3. Pre- and post-evaluation self-efficacy questionnaire. 4. Post-evaluation questionnaire.	1. Case study analysis. 2. Inductive content analysis of interviews and questionnaire responses. 3. Mixed methods convergent analysis across data sources.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
7.5 (b) How does the self-efficacy of the participant influence their difficulty level setting?	Qual. & Quant.	1. Log-files. 2. Post-evaluation interviews. 3. Pre- and post-evaluation self-efficacy questionnaire. 4. Post-evaluation questionnaire.	1. Case study analysis. 2. Inductive content analysis of interviews and questionnaire responses. 3. Mixed methods convergent analysis across data sources.
7.6 How does the self-efficacy of the participant affect their goal setting?	Qual. & Quant.	1. Log-files. 2. Post-evaluation interviews. 3. Pre- and post-evaluation self-efficacy questionnaire. 4. Post-evaluation questionnaire.	1. Case study analysis. 2. Inductive content analysis of interviews and questionnaire responses. 3. Mixed methods convergent analysis across data sources.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
7.7 How does the self-efficacy of the participant affect their goal-commitment?	Qual. & Quant.	1. Log-files. 2. Post-evaluation interviews. 3. Pre- and post-evaluation self-efficacy questionnaire. 4. Post-evaluation questionnaire. 5. Researcher observation.	1. Case study analysis. 2. Inductive content analysis of interviews, observations, and questionnaire responses. 3. Mixed methods convergent analysis across data sources.
7.8 How does the self-efficacy of the participant affect their reaction to success or failure?	Qual. & Quant.	1. Log-files. 2. Post-evaluation interviews. 3. Pre- and post-evaluation self-efficacy questionnaire. 4. Post-evaluation questionnaire. 5. Researcher observation.	1. Case study analysis. 2. Inductive content analysis of interviews, observations, and questionnaire responses. 3. Mixed methods convergent analysis across data sources.

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Table G.1 – continued from previous page

Research Question	Data Types	Data Sources	Data Analysis
7.9 How does the primary school context affect the experience?	Qual.	1. Researcher observation. 2. Expert observation. 3. Pre- and post-evaluation questionnaire.	1. Inductive content analysis of interviews, questionnaires, and observation field notes.
7.10 Is iFitQuest appealing to a younger demographic?	Qual. & Quant.	1. Researcher observation. 2. Pre- and post-evaluation questionnaire. 3. Post-evaluation interviews.	1. Inductive content analysis of interviews and observation field notes. 2. Mixed methods convergent analysis across data sources. 3. Case study analysis. 4. Self-reported enjoyment descriptives.
7.11 Do the design requirements of the iFitQuest system fit within the primary school context?	Qual.	1. Researcher observation. 2. Expert observation. 3. Pre- and post-evaluation questionnaire. 4. Post-evaluation interviews.	1. Inductive content analysis of interviews and observation field notes. 2. Mixed methods convergent analysis across data sources. 3. Case study analysis.

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