Encouraging Physical Activity with Gamification Approaches: Goal-setting, Social Community, and "*FitPet*" Game-based Mobile Application

by

Xin Tong

B.Eng., Beijing University of Posts and Telecommunications, 2013

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

in the
School of Interactive Arts and Technology
Faculty of Communication, Art and Technology

SIMON FRASER UNIVERSITY

Summer 2015

Approval

Name: **Xin Tong**

Degree: **Master of Science**

Title: ***Encouraging Physical Activity with Gamification Approaches: Goal-setting, Social Community, and "FitPet" Game-based Mobile Application***

Examining Committee: **Chair:** Lyn Bartram
Graduate Chair

Diane Gromala
Senior Supervisor
Professor

Chris Shaw
Co-Supervisor
Associate Professor

Carman Neustaedter
External Examiner
Associate Professor
School of Interactive Arts and Technology
Simon Fraser University

Date Defended/Approved: August 17th, 2015

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics,

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University;

or has conducted the research

c. as a co-investigator, collaborator or research assistant in a research project approved in advance,

or

d. as a member of a course approved in advance for minimal risk human research, by the Office of Research Ethics.

A copy of the approval letter has been filed at the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

update Spring 2010

Abstract

Wearable trackers and mobile applications can facilitate self-reflection of doing physical activity. The gamification process incorporates game design elements with persuasive systems in order to encourage more physical activity. However, few gamification strategies have been rigorously evaluated; these investigations showed that using the same gamification mechanism to promote physical activity could have contradictory effects. Therefore, I developed *FitPet*, a virtual pet-keeping mobile game for encouraging activity. I evaluated its effectiveness, and compared it with the goal-setting and social community strategies in a six-week field study. The findings revealed social interaction were the most effective intervention. Contrary to prior research, goal-setting was not perceived as an effective way to provide motivation compared to social interaction overall. Although *FitPet* was not able to promote significantly higher activity, participants showed great interests in this approach and provided design insights for future research: implementing social components and more challenging gameplay.

Keywords: Gamification; motivation; self-reflection; physical activity; goal setting; persuasive technology

Dedication

To my respectful supervisors, Diane and Chris, who guide me with their wisdom and treat me as their friends. To my dear friends and lab mates, who accompany me through this wonderful journey with joy at the Pain Studies Lab. To Caesar, who is always there supporting me and reminding me that dawn is coming whenever I feel the dark night is too long to hang on. To my parents, who brought me to this amazing world, teach me how to love, and show me how to become a wonderful person.

Acknowledgements

My special thanks and deepest appreciation to Dr. Diane Gromala and Dr. Chris Shaw, being the most awesome supervisors I have ever met. They are also my dearest friends giving valuable guidance and help through my entire graduate studies. Thank all Pain Lab members, Jeremy, Mehdi, Eylul, Cheryl, Ashfaq, Emre, Mahsoo, Mark, Maryam, Dimple and Gillian. I learned a lot from you and really enjoyed the experience of working with you. Thanks to Amber, who helped me with the graphic design of the *FitPet* game and who is also the best game artist inspires me all the time.

Table of Contents

List of Tables

List of Figures

List of Acronyms

HCI	Human Computer Interaction
SFU	Simon Fraser University
CDC	Centers for Disease Control and Prevention
TTM	Transtheoretical Model
QoL	Quality of Life
ANOVA	Analysis of Variance
SD	Standard Deviation
HP	Health Points

Glossary

Gamification	Gamification is the use of game design elements in non-game contexts.
A Step	A unit cycle of walking behaviour, showing the relationship between each stage of the walking cycle and the change in vertical and forward acceleration.
Transtheoretical Model (TTM)	A theory originally developed in 1977 and continuously expanded by Dr. James O. Prochaska and colleagues, also referred to as “TTM.” Comprised of several theories of psychotherapy, it argues that individuals change their behaviour gradually, by advancing along a series of steps (including Pre-contemplation, contemplation, Preparation, Action, Maintenance and Termination).
Persuasive Technology	Persuasive technology is broadly defined as technology that is designed to change attitudes or behaviors of the users through persuasion and social influence, but not through coercion.
Quantified System	Quantified System incorporates technology such as sensors and wearables to acquire data on various aspects of an individual’s life—especially health and fitness—with an aim to improve self-sensing, self-awareness and human performance.
Personal Informatics	Personal informatics is a class of tools that help people collect personally relevant information for the purpose of self-reflection and self-monitoring. These tools help people gain self-knowledge about one's behaviors, habits, and thoughts.
Serious Games (ExerGames)	Serious games are simulations of real-world events or processes designed for the purpose of solving a problem. Although serious games can be entertaining, their main purpose is to train or educate users, though it may have other purposes, such as marketing or advertisement.

Chapter 1.

Introduction

A sedentary lifestyle is a contributing factor to chronic disease. Regular physical activity is critical to everyone's physical and psychological health, regardless of their weight being normal, overweight, or obese (National Center for Health Statistics (U.S.) 2005). Yet despite the importance of physical activity, many adults in the North America do not get enough exercise according to the U.S. Centers for Disease Control and Prevention ("CDC - Facts - Data - Physical Activity - DNPAO" 2015).

One method for substantially improving the quality of life is to perform physical activity, which can both increase mental and physical health and reduce the risk of potential chronic diseases. Although people recognize that performing regular physical activity is essential for health, many people are not physically active on a regular basis.

Tools such as mobile devices and wearable technologies have been shown to help people manage their health and wellness. Of particular interest are technologies that are designed for activity tracking and promoting behaviour changes in everyday life. These technologies hold the potential to assist with counteracting the lack of regular physical activity by motivating people to develop and maintain a more active and healthier lifestyle. Numerous persuasive systems aimed at promoting physical activity have been developed and researched in recent years. These systems capture and measure activity-related parameters and present the measured data to the user in various ways.

In particular, mobile and wearable technologies can offer a host of sensing technology and data visualization tools, which allow for captured and quantified data to be stored, analyzed and communicated. Furthermore, researchers and commercial companies alike have been developing various systems designed to promote physical activity.

In the light of the criticism toward gamification and a relative lack of rigorous studies evaluating its effectiveness, in this thesis, I set out to evaluate people's acceptance of gamified information visualization strategies, initially with a user study. Next, I developed a research prototype based on game ideas. Finally, I conducted a six-week field study with a different gamification element for each experimental group. At the conclusion of the field study, the data was analyzed and findings were finally concluded. The effectiveness of goal-setting strategy relied highly on individual's personality. Social interaction and communication gamification strategy was the most effective one in terms of promoting more steps. Although the *FitPet* game-based approach was not successful at encouraging significantly more steps compared to the control group, participants accepted and enjoyed the generally game design idea. However, more game mechanics should be implemented in order to keep players within the flow channel of engaging with the game. The findings of the study revealed how people liked various gamification design strategies and what should be taken into specific consideration when designing for motivation and behavior change. Hopefully, these design challenges and opportunities may shed light on gamification design and provide other designers and researchers with enlightening insights.

Future work would be to modify current design strategies, and conduct in situ studies with the targeted user population for a longer time period (more than a year). Such studies will expose important issues, for example, how the systems are used for everyday experiences, where the technology is brittle, and user reactions to activity inference and the presentation of those inferences.

In this chapter, I first introduce the research questions this thesis is tended to answer. Then I explain the motivation and goals of conducting research on this topic. Next, the research approach and methodology are briefly discussed. Last, the main content of all chapters are listed as a form of the research overview.

1.1. Research Question: Can Certain Gamification Strategies and Game Mechanics Effectively Promote Physical Activity?

Digital technology is increasingly being adopted to promote physical activity and reduce sedentary behaviour in the general population. It offers a practical way to motivate self-managed physical activity. However, for any behaviour change technology to be effective, the strategies that promote change need to be examined along with reasons that undermine to behaviour changes.

In the past decade, a number of innovative health-related programs designed to promote an increase in physical activity introduced novel technologies to reduce the cost of continuous involvement of clinical personnel required to promote and maintain healthy behaviours in patients. Many of these include techniques that transform physical exercise into engaging individual or social games that often mix real and virtual environments (Björk et al. 2002). In an alternative approach, pedometers – small electronic devices that monitor individual step counts, have been used as a ubiquitous and unobtrusive motivational technique available anytime and anywhere (C. E. Tudor-Locke et al. 2002) (Chan, Ryan, and Tudor-Locke 2004) (Consolvo et al. 2006).

Some of these “quantified systems” provide numerical numbers for self-knowledge and self-reflection, which has been termed as “personal informatics”. Such quantified systems can facilitate the collection and storage of personal information. It is believed that self-reflection leads individual to reconsider and possibly change their attitudes towards lifestyle changes. However, there are other systems that present physical activity data using game-based mechanics, defined as gamification. This approach has been assumed to be more fun and enjoyable, thus motivating users or players to become more physically active.

Gamification has the potential to engage people at an emotional level, which is considered to be far more powerful than typical transactional engagement strategies (Burke 2014). The gamification techniques – points, virtual rewards, levelling up, badges, peer obligation, social currency, missions and challenges – are part of the new area of gamification, with early signs of great potential for lifestyle improvements

(McCallum 2012). Concluded from the definition and applications of gamification, gamification is not about applying technology to old engagement models. Rather, gamification is thought to create entirely new engagement models, targeting new communities of people and motivating them to achieve goals they may not even know they have.

Gamification approaches have become popular in recent years (Burke 2014) and are utilized as a design trend in applications for promoting healthy behavior changes. Nevertheless, many researchers have also criticized gamification mechanics. Furthermore, current research has not covered or evaluated most gamification techniques yet. Therefore, it remains unclear whether certain gamification approaches are effective in the context of physical activity.

Therefore, the major research question of this thesis is: will certain gamification approaches, including goal setting, social interaction, and a game-based virtual pet-keeping mobile application, be effective for promoting more physical activity? If there is an effective gamification method, how can that strategy provide motivation and why? Besides, I also wanted to figure out the design challenges and opportunities for developing such research prototype and persuasive technologies for encouraging motivation for lifestyle behavioral changes.

1.2. Approach and Methodology

In my thesis, I adopted the following procedure for answering my research questions: Exploring the questions – Conceptualizing the demands – Building Prototype – Testing and observing – Reflecting.

In exploring and conceptualizing phases, I designed two types of data visualization and compared it with *FitBit* bar charts visualization. One is an aesthetic visualization with a ringmap structure, and the other is a gamified visualization representing physical activity level using a virtual pet's condition. Study One evaluated the effectiveness of three types of data visualization through a test, including bar charts, ringmap, and the gamified approach. Results indicated that participants had the highest accuracy with bar charts visualization. It was also perceived as the most readable one. However, participants gave a significantly higher rating for the virtual-pet gamified solution considering the empathy and attractiveness of three visualizations.

The first user study is the inspiration of idea that led me to my thesis question and the second subsequent main study. So I went further and developed a research prototype called *FitPet*, which is an accelerometer-based mobile application, intended to motivate people to walk more during their daily routine using a virtual pet-keeping game by associating steps with the gameplay.

In the testing and observing stage, I set out to evaluate the relative effectiveness of the quantified and gamified approaches of representing physical activity data, where study two was brought into field. Study Two focused on two commonly used game strategies and one novel game based mobile application – goal-setting, social interaction (competition and collaboration), and *FitPet*. Twenty-three participants took part in the six-week field study, which included pre-intervention, intervention, and post-intervention phases. The results revealed that the goal-setting control group yielded same walking behaviour as the *FitPet* experimental group, whereas social community experimental group had significantly increased in steps compared to the other two.

In the meantime, three semi-structured interviews with each participant after each phases indicated that the social challenges mechanic was perceived as the most motivating and encouraging approach by participants, while goal-setting was considered meaningless by half of the participants. As for the *FitPet* game, although participants gave positive feedback regarding the overall design concepts, they suggested in order to be effective on motivating more activity, the application should implement more feedback, more challenging tasks, and social collaborative chances.

1.3. Research Overview

In Chapter One, research questions, goals and motivations, research methodology and thesis overview are introduced.

Chapter Two demonstrates the research background and relevant literature on utilizing persuasive technologies to promote physical activity. Firstly, physical activity levels and their relationship to general health are investigated. Second, gamification and game mechanics are reviewed in terms of how they may provide motivations for promoting physical activity from the theoretical level. Third, similar prior research which conducted by others are discussed in relation to their gamification mechanics, prototypes and study results.

Chapter Three mainly describes the first user study that inspired this thesis, along with its results and findings. Results from the first study validate my hypothesis that a virtual pet figure visualization and representation can be more attractive and bring more empathy for individuals than traditional bar charts and aesthetic visualizations. This inspired the design and development of my research prototype, the *FitPet* mobile application.

Chapter Four mainly illustrates how the design decisions were made while developing *FitPet* application. Step-capture algorithms, gamification strategies and the final appearance of the game are further discussed with detailed information.

In Chapter Five, the second user study, which evaluated the effectiveness of three gamification strategies in a six-week field study with three phases, is introduced. Study details, procedure, methods, results and findings are explained and illustrated in details.

The overall research findings of both the quantitative and qualitative analysis, design challenges and opportunities, research limitations and implications for further gamification mechanic development are elaborated in Chapter Six.

In the concluding chapter, my research motivation, design ideas, procedure and findings are summarized, and then future research is proposed.

Chapter 2.

Research Background and Literature Review

Numerous persuasive systems have been designed and developed for promoting physical activity over the past two decades. Methods for encouraging more physical activity and related behaviour changes like self-monitoring, goal-setting task, and social competition, have been and continue to be incorporated into the design of persuasive systems. Incentive approaches vary from virtual and physical rewards to digital games and gamification. To evaluate the effectiveness of proposed methods and approaches, common research prototypes and applications used pedometers, mobile phones and health trackers (like *FitBit*, *JawBone*, *Nike FuleBand*, *Garmin*, and so on).

In this chapter, I first explain the reason why it was important to promote more physical activity and how it matters to health. Next, commercial and academic approaches for encouraging physical activity are introduced. Relevant research, with quantified and gamified systems, are reviewed and analysed. Finally, interventions adopted in this thesis are listed and discussed, including goal-setting, self-monitoring and self-reflection, social interaction and physical activity-game mapping. These interventions were implemented and then evaluated in the user study in Chapter Five.

2.1. Physical Activity Matters to Health

Recently, special interest has been given to persuasive systems and wearable technologies designed to support health-related behaviour change, since it has the potential to improve overall quality of life (QoL). A wide range of literature has pointed out the fact that to increase people's QoL and fitness, encouragement to become more physically active improves their outcomes (Ferrucci et al. 2000) (Obi, Ishmatova, and Iwasaki 2013).

Performing physical activity can improve both physical and mental health (Pate et al. 1995) (Chan, Ryan, and Tudor-Locke 2004), and reduce the risk of various diseases, such as premature mortality (Pekkanen et al. 1987), coronary heart disease (Thompson et al. 2003), type II diabetes ("Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin" 2002), colon cancer (Slattery and Potter 2002), obesity (Wing and Hill 2001), and osteoporosis (Vuori 2001). Moreover, for mental health, it has also been shown that more physical activity can improve symptoms associated with mental health conditions such as depression and anxiety (Taylor, Sallis, and Needle 1985) (Chan, Ryan, and Tudor-Locke 2004).

Although it is important to keep an active level of physical activity, many adults do not get enough exercise in the North America. According to CDC, the prevalence of chronic disease continues to rise and is now responsible for over 70% of U.S. healthcare expenditures. Some of the most crucial factors inducing those chronic conditions are behavioural, such as smoking, physical inactivity, excessive food intake, and diets heavy in trans fats. A successful change in these behaviours is a fundamental aspect of both prevention and effective management of chronic conditions, and important contributor to health and wellbeing in a broad way. Thus, physical activity matters and it is necessary to enhance the overall level of physical activity ("CDC - Facts - Data - Physical Activity - DNPAO" 2015).

2.2. Persuasive Technology Solutions for Health, Healthcare and Motivating Physical Activity

Due to the low cost, high penetration, and integration in individual's everyday life, mobile phones, wearable health sensors, web applications, and social networking tools hold great potential for supporting people as they strive to adopt and sustain health-encouraging behaviors.

Many technologies enable an individual's access to personal information through web-based resources, pedometers and other wearable sensors, and smart phone Apps. In this section, prior and current technology solutions for commercial and experimental purposes are introduced and reviewed, and how those solutions and information were visualized for personal informatics is discussed. Last, the influence of those technology solutions have had over participants' behavioral and motivational changes is discussed.

2.2.1. Wearable and Mobile Computing Technologies and Systems

Technologies have long been used to track and encourage physical activity, from heart rate monitors and bicycle odometers to web sites that support goal setting and self-monitoring. Wearable and mobile quantified systems can measure one or more parameters related to physical activity, presenting data with numerical information.

Physical Activity Detection with Commercial Devices

The pedometer is the most common commercial device, which is an on-body sensing device that detects the number of "steps" the user takes. It uses a simple "inference model" in which alternating ascending and descending accelerations are counted as steps. This means any manipulation of the device that activates the sensor is interpreted as a step. Pedometers have been widely used in clinical settings as an intervention for motivating more physical activity (Bravata et al. 2007). Formal assessments of pedometer intervention's effectiveness were also conducted to provide insights of what motivate individual's behaviour changes.

In the general procedure of a pedometer intervention, participants are given a pedometer to wear every day as they perform their usual activities. Tudor-Locke et al. observed a 26.9% increase of steps over baseline level (C. Tudor-Locke 2002). Therefore, we could conclude that a single pedometer can heighten individual's awareness of physical activity.

In recent years, more advanced and convenient commercial systems are growing popular in the market, such as the *FitBit* (as shown in Figure 2.1), *Jawbone UP*, *Garmin*, *Nike+ FuelBand*, and so on. They are mostly GPS-based or accelerometer-based activity trackers. Steps taken, calories consumed, active minutes, and distance traveled can be tracked and the data will be presented from either the wearable device, or its mobile and web applications, sometimes both. Most devices allow users to set up goals and track goal completeness through the health tracker and websites or mobile apps.

Some of them, like *FitBit*, incorporated gamified elements into the system, such as social groups, challenge competitions, and virtual rewards (like badges).

Figure 2.1 Wearable Health Tracker *FitBit* and its Mobile Application

In addition to wearable health trackers, globally, there has been an increase in Apps that are designed to improve health through better lifestyle choices, including tracking food intake (such as *Lose It*), tracking activity (*My Fitness Goal*), encouraging healthy food and activity replacements (*Swap It, Don't Stop It*), retaining mental flexibility (*Brainy App*), and support for giving up smoking (*My QuitBuddy*). In some cases, games and gamification techniques have been implemented to make the Apps more likely to be used and to encourage compliance with the lifestyle changes (*Eat this, not that!*).

In addition to the use of smartphones and health trackers, the use of game-based technology to encourage physical activity as part of a lifestyle improvement is common. *Ubisoft* has included a series of exercise routines that have been purposely designed to help older adults stay active and mobile as well as giving people of all age's tools for lowering their blood pressure in the 2012 release of their *Yourshape Fitness Evolved* product. *Nike* has also introduced *Nike Kinect + Training* which enables players to count activity in the video game towards their *Nike+ Fuel* pool in the cloud. *Nintendo's Pocket Pikachu* is a pedometer with a virtual character that responds to step counts. Marketed to children, *Pikachu* encourages physical activity by learning tricks and becoming happier as the step count increases. *Get Up Move* is another program to motivate weight loss using a video game called *Dance Dance Revolution* (Ahtinen, Huuskonen, and Häkkilä 2010), where users physically move in a pattern on a special floor mat.

Physical Activity Detection with Experimental Research Prototypes

Usage of pedometers and mobile devices helps individuals understand their current level of activity, set achievable goals and monitor their progress towards the goals, either individually or in a social setting. Here, I discussed prior research prototypes based on the gamification strategies adopted.

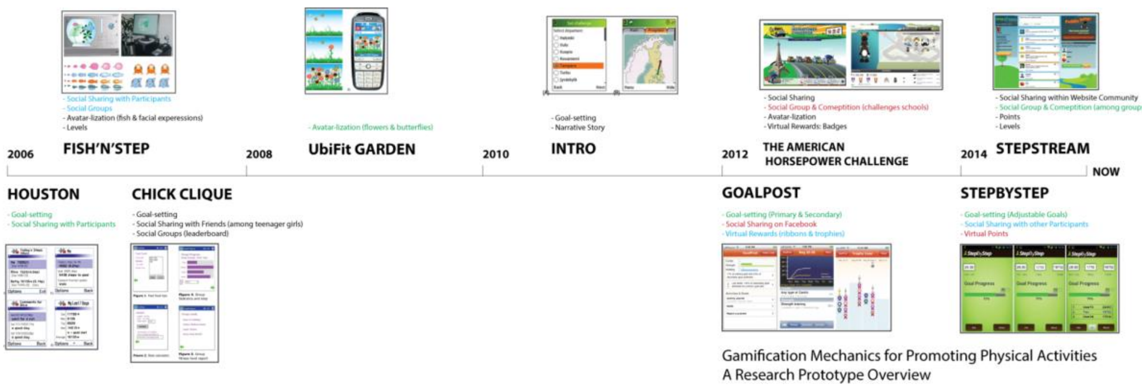


Figure 2.2 The Overview of Related Research Prototypes

Social Communications and Interaction: In *Hounston*, a research prototype designed by Consolvo et al. (Consolvo et al. 2006), groups of friends wearing pedometers could share each other's goals and progress as well as motivational messages via mobile phones. The results revealed that sharing activity-related information resulted in social pressure to meet one's goal, beat a friend, or not have the lowest step count. Similarly, in *Chick Clique* (Toscos et al. 2006), small groups of users share their step counts and progress toward daily step count goals with each other via their mobile phones. However, the users of *GoalPost* and *GoalLine* (Munson and Consolvo 2012) were hesitant to share their activity information with others on *Facebook*. A more recent research prototype *StepByStep* (Zuckerman and Gal-Oz 2014) is designed with gamification strategies: goal-setting, leaderboard comparison, and virtual points features. In their three-week long field study, Zuckerman and Gal-Oz demonstrated that gamified versions offering virtual rewards and social comparison were only as effective as the quantified version. In other words, the participants in the gamification group did not benefit more than those in the control group. The authors concluded that the specific gamification incentives and mechanics used in *StepByStep* were ineffective.

Virtual Avatar Visualization and Representation: Fish'n'Step (Lin et al. 2006) uses personal goals, social influence, and a non-literal, aesthetic display to promote physical activity, especially more steps. The user's step count is linked to the emotional states, growth, and activity of a virtual fish in a virtual tank – a tank that includes the fish of other users. The fish tank is displayed in a public kiosk in the users' office and on personal websites for an individual progress view. The study results showed that when fish avatar was not aesthetically pleasing, participants stopped looking at the tank and some even stopped using the system all together. The concepts of using virtual avatar to represent physical activity data was further researched in Consolvo et al.'s *UbiFit Garden* system (Consolvo et al. 2008). It is a system which uses small sensors and mobile display to visualize people's physical activity. It uses virtual flowers and butterflies to represent the activity levels and goal completeness of the users.

Game-based Approach: Games are also deployed into persuasive technologies and utilized together with trackers to promote physical activity. Yet the effectiveness of current research prototypes seems to be less powerful than simpler systems like UbiFit Garden. In a map-based game called *Intro* (Ahtinen, Huuskonen, and Häkkilä 2010), it records steps from a mobile phone's accelerometers, and users "travel" on the virtual map where their locations are decided by their step count. Participants rated the app to be motivating and appealing in a one-week user study. But the effectiveness in terms of physical activity improvement was not formally evaluated. *The American Horsepower Challenge* is a location-based competition game aimed at increasing students' physical activity (Xu et al. 2012). Students wore pedometers whose data were later converted into a web-based game later. The goal of *The American Horsepower Challenge* is for one school's students to win a virtual race against students in other schools. However, Xu et al. reported finding a drop of steps to below the baseline level.

2.2.2. Transtheoretical Model: Steps of Motivation for Behaviour Change in Everyday Life

Desired changes can be achieved without a significant disruption of one's current lifestyle. For example, studies have demonstrated that individuals who walked at least 10,000 steps a day were more likely to maintain their desired weight (C. E. Tudor-Locke et al. 2002) and sugar level in diet.

Individual behaviour change, including physical activity, has become a subject of active investigation in the areas of cognitive science and clinical psychology. One of the most accepted theoretical model by psychology community of how changes happen is the Transtheoretical Model (TTM) introduced by James Prochaska (Prochaska and Velicer 1997). TTM argues that individuals change their behaviour gradually, by advancing along a series of steps. These steps vary from pre-contemplation in which individuals have not realized the need for change, to termination in which the new behaviour has become so habitual that there is no longer any danger to relapse.

TTM has been successfully used to design interventions for undesirable behaviours, like alcoholism, smoking, and domestic violence (DiClemente et al. 1991), and to motivate increase in exercise and other types of physical activity (Dallow and Anderson 2003) (Marshall and Biddle 2001) (Riebe et al. 2005). However, traditional techniques inspired by TTM rely on significant clinical resources for individuals who seek the change. There is a need to develop more innovative and cost-effective intervention programs that supplement or replace meetings with a therapist (Riebe et al. 2005).

In TTM, six steps are considered to be crucial to the behaviour changes. As interpreted in prior research by Lin et al. (Lin et al. 2006), the six steps are "1) Pre-contemplation: individuals have no recognition of the need to change and, consequently, no intention to take action; 2) Contemplation: intention to take action within foreseeable future (next six months); 3) Preparation: intention to take action within immediate future (next thirty days and having taken initial preparatory steps); 4) Action: practicing new behaviour for three to six months; 5) Maintenance: continuing commitment to sustaining behaviour; 6) Termination: overt behaviour will never return, and there is complete confidence that one can cope without fear of relapse". For an exercise program, termination means that the behaviour is so ingrained that external reinforcements are no longer necessary.

Therefore, in this research, I divided the participants into TTM levels and they were assessed both before and after the six-week study using TTM definitions.

2.3. Game, Rewards, Gamification and Motivation

2.3.1. Games, Rewards, and Gamification

It is necessary to define game, gamification, and rewards programs and know their similarities and differences. According to the book *Gamify* (Burke 2014), video games, rewards programs and gamification are similar in a few ways: they engage "players" voluntarily; they use game mechanics such as points and levels; they are interactive; they incorporate progression to move players to the next level.

Gamification is the use of game design elements in non-game contexts (Deterding et al. 2011). In this thesis, it works with physical activity in a non-entertainment context, so gamification approaches were adopted.

However, the differences are more important than the similarities. All three approaches engage people on different levels with a different purpose. In the book *Gamify* (Burke 2014), the author claims that "Games engage players on a whimsical level to ***entertain*** them. Rewards programs engage players on a transactional level to ***compensate*** them, while gamification engages players on an emotional level to ***motivate*** them."

In the book *Drive* (Pink 2011), Daniel Pink examined the science of motivation and how extrinsic and intrinsic rewards affect behaviours. He cited numerous studies showing that extrinsic rewards are not sufficient enough to sustain engagement, and sometimes have the opposite effect. Extrinsic rewards can certainly be used to motivate people, but the motivation occurs at a transactional level. Intrinsic rewards sustain engagement because they engage people at an emotional level.

2.3.2. Game Mechanics Providing Motivation for Physical Activity and Health

From research and studies with *Super Better*, McGonigal drew the conclusion that games provide huge motivation to people (McGonigal 2011). There are also a number of applications that motivate increases in physical activity in a fun way by engaging individuals in games that mix real and computing worlds, as discussed earlier in Chapter 2.2. These games became known as *Exergames* (Serious Games).

Interactive videogames that combine player movement, engaging recreation, immediate performance feedback and social connectivity via competition, have been shown to promote motivation for, and increase adherence to, physical exercise among children and young adults (Chan, Ryan, and Tudor-Locke 2004) (Epstein et al. 2007) (Ralph Maddison et al. 2007) (Baranowski et al. 2008). For example, *Tagaboo*, a collaborative children's game, focuses on developing coordination through playful interaction (Konkel et al. 2004) ; *Exercise Bicycles* enriches the experience of an indoor exercise bicycle in engaging users in a Virtual Environment single-player game (Mokka et al. 2003). In these games, strong and attractive animated characters have the same diseases as children who play the game, thus providing positive role-models and reducing the stigma associated with the disease.

2.3.3. Elements of Motivation in Gamification Mechanics

Gamification uses primarily intrinsic rather than extrinsic rewards. In Pink's book *Drive* (Pink 2011), he concludes that intrinsic motivators have three essential elements – Autonomy, Mastery and Purpose. People are motivated by the desire to maintain a sense of autonomy, progress toward mastery, and engage with a purpose larger than themselves. Their definitions and how it motivates people are quoted as following:

Autonomy *– "the desire to direct our own lives. In effective gamified solutions, players volunteer to participate, and they make choices about how they will proceed through the challenges to achieve their goals. Players are given the opportunity to discover and learn using different paths through the solution. Players are given goals, tools, rules, and a space to "play" without being directed on the next steps to take."*

Mastery *– "the urge to make progress and get better at something that matters. Gamification provides the positive feedback and easy on-boarding that can motivate people to start performing better in a chosen area. But mastery is not an attainable goal. Instead, it is a journey. There are many signposts along the way that indicate progress, but there is never an end point. Gamification is about getting better at something."*

Purpose *– "the yearning to act in service of something larger than ourselves. By definition, gamified solutions are distinguished from traditional games by their purpose. Gamification is focused on one or more of three objectives: changing behaviours, developing skills, or driving innovation. Gamification starts and finishes with a purpose that is centered on achieving meaningful player goals, a goal that might be much larger than the player him/herself."*

2.4. Interventions in Promoting Motivation for Health Behavior Change

There are a number of advantages to using computerized interventions, wearable and mobile computing technologies for promoting health. In addition to being cost-efficient, they can be delivered anytime and anywhere, or "just in time" for a decision – when they can have the highest potential impact. In some field studies, motivational messages delivered at the time of decision-making inspired individuals to take simple steps to improve their health, such as choosing a staircase over the escalator (Intille 2004).

At the same time, sensor technologies can be used to make these messages highly personalized. For example, artistic sculptures resembling human figures were used to enhance individuals' awareness of their posture (Jafarinaimi et al. 2005). Often, these techniques incorporate emotional aspects. For example, an attachment to virtual creatures inspired technological health interventions for children with chronic disease (Lieberman 1997).

Most of the prototypes from prior research studies used the appearance of a virtual avatar to represent the user's physical activity level. However, there were contradictory effects shown regarding this mechanism. For instance, in *Fish'n'Step* (Lin et al. 2006), the users started to feel frustrated and did not care about the virtual fish anymore if they performed worse than others, and if there were not a significant increase in steps, whereas in *UbiFit Garden* (Consolvo et al. 2008), in general, individuals who used the prototype felt more encouraged, in general, than the control group.

Furthermore, such representations are considered to be more of a 'one-way projection', from the display of technology to the users. However, none of those research studies utilized an interactive virtual pet-keeping game as a design strategy for encouraging behavior changes. Moreover, an interactive virtual pet-keeping game requires user testing and investigation in order for researchers to fully understand how individuals will respond to a more interactive gamification approach. Therefore, in this thesis, to better understand the motivation and engagement aspects in terms of how individuals interact with such a gamification approach, the research prototype, *FitPet*, was designed.

There are a variety of gamified intervention techniques developed over the years to motivate behavior changes. Examples of these techniques include goal-setting, self-assessment, or monitoring of achieved progress (Hardeman et al. 2000), and so on. Two particular approaches that influenced the current project include motivating behavior change by *cultivating strong internal locus of control through care of pets or plants* (Langer and Rodin 1976), and *incorporating social influences through friends and co-workers participation in a community* (McLean et al. 2003). Four major techniques used in designing the prototype in this thesis were discussed below.

2.4.1. Self-monitoring and Self-reflection

The main aim of quantified systems is to facilitate self-reflection through self-monitoring on the information and data presented. Schön (Schön 1983) proposed two types of self-reflection: reflection-in-action, and reflection-on-action. Reflection-in-action refers to contemplation at the time of doing, whereas reflection-on-action refers to contemplation of previous activities. Recent research shows that both of them can potentially lead users to change their level of physical activity (Ploderer et al. 2014).

Wearable and mobile systems can facilitate reflection-in-action by providing real-time feedback at the time of performing activities, as well as reflection-on-action by providing historical activity information and data.

Many applications have functions for saving historical data and viewing physical activity related data. Popular commercial products, like *FitBit*, *Jawbone*, and *Garmin*, all have physical data displayed data on both the small display of wearable devices, and related mobile and website applications. Research prototypes also provide such features. *Houston* tracked steps based on user pre-set goal, collecting data from users' pedometers (Munson and Consolvo 2012). *UbiFit Garden* automatically tracks physical activity with user manually journaling (Consolvo et al. 2008).

When combined with goal-setting, self-monitoring has been shown to be an effective ways at promoting behaviour changes towards a positive side (Michie et al. 2009). Most of the prototype tracks steps, like *Fish'n'Step*, *Houston, and so on*, while *StepByStep* tracks active minutes instead of steps data (Zuckerman and Gal-Oz 2014).

2.4.2. Goal-setting

Goal-setting and real-time feedback are regarded as the common techniques for facilitating reflection and behavior changes. Although both goal-setting and real-time feedback are utilized in numerous non-game and non-gamified situations, they are regarded as game elements by some researchers (Deterding 2015).

Prior research reveals that goals have been shown to be effective when they are crucial to the individuals, especially self-set goals rather than assigned ones. Individuals receive positive feedback as progress towards goal completeness after they set an attainable goal.

Many research incorporate goal-setting into their research prototypes as the strategy to promote physical activity. In prior research (Bravata et al. 2007), Bravata et al. identified that an additional significant motivator for increasing physical activity is setting a step goal. They reported that participants who were given either a fixed or personalized step goal, tended to have more steps than who were not. *Houston*

(Consolvo et al. 2009) participants were asked to set a daily step goal based on their baseline level. *UbiFit* (Consolvo et al. 2008) also deployed goal-setting, where their users need to set primary and alternate weekly physical goal each week. In the first and second user study of *StepByStep* (Zuckerman and Gal-Oz 2014), participants were asked to set up their active minutes goals, either a fixed one or an adjustable one based on experimental group conditions. However, the drawback of goal-setting is that individual tends to give up and feel frustrated when the goals are not achievable during the goal-setting task period.

2.4.3. Social Communications and Interaction: Competition and Collaboration

Social comparison is the most commonly used social mechanic in research prototypes. It refers to the process of evaluating one's abilities by comparing them with others. However, available social interaction covers social competition, collaboration in groups or community, networking, and sharing information. But the effectiveness of collaboration in community and social networking for activity promotion has not been investigated in research field yet.

As concluded from former research, social comparison and sharing information are not always an effective approach to activity promotion. There are certain restrictions for individuals to engage with others. For example, in *Houston* (Consolvo et al. 2009), users can share daily steps goals and progress with friends, keep an eye on their friends progression, and send motivational messages to each other. Participants in their three-week user study reported that sharing information actually creates social pressure to meet one's goal, compete with friends, and not rank last. In *Fish'n'Step* (Lin et al. 2006), some users were in the team condition and competing against other teams. However, their results showed that some participants perceived the avatar as not attractive and pleasing, and they even stopped checking the rank. They felt sometimes awkward and not always motivated to share with strangers. Also, in three-week user testing with the prototype *StepByStep* (Zuckerman and Gal-Oz 2014), researchers found that the leaderboard in the group condition is not an effective method for promoting motivation.

In addition to research prototypes, commercial applications have larger and mature communities for social communications and networking in a larger scale population and more open ways. For instance, *FitBit* built a web-based community and platforms for volunteer construction and participation. Within each activity group, a leaderboard of all the group member's rankings are visualized as bar charts graph with user's avatar in each. In the *FitBit* mobile app, there is a particular way of social interaction, called "Mobile Challenges". Mobile Challenges are created by the members and competitions happen in a more dynamic and active way. Competitions in Mobile Challenge provide users with real-time notifications and a really clear competition goal, just like participating in real world physical activity competition. In this Mobile Challenge features, one can start competition with his/her selected friends. Different from the Website Community group, Mobile Challenge happens after one sends out invitations and others accept it. There are chat windows, and individuals can cheer on others, and view the real-time ranking within the Mobile Challenge time period. At the end of a Mobile Challenge, the winner receives a virtual trophy.

2.4.4. Physical-Activity-Game Mapping: Virtual Rewards for Games

Virtual Rewards are digital or symbolic incentives that are given to users following desired responses in an attempt to reinforce those positive responses. Five individual virtual rewards and social rewards are suggested as functions in gamified approaches by Antin and Churchill (Antin and Churchill 2011): badges, goal-setting, instructions, reputation, status/affirmation and group identification.

Game-based approaches for encouraging physical activity can be used to support traditional intervention schemes that enable people, especially older adults in staying active and healthy for a longer time (Drobics and Smith 2014). These techniques are especially useful as they improve the motivation of the users and thus improve the effectiveness of the intervention.

Research projects revealed users' different responses towards various types of virtual rewards in gamification methods. For example, in *UbiFit Garden* (Consolvo et al. 2008), the mobile phone's screen background shows individual's physical activity and goal attainment within one week. The three-month field experiment found that the glance able display contributed for remaining participants to be active. However, it is not always an effective means to promote activities using rewards. In *GoalLine* (Munson and Consolvo 2012), users felt indifferent to the virtual rewards, like ribbons and trophies,.

2.5. Discussion

Gamification relies on elements characteristic of games to shape user behaviour and motivation (Mekler et al. 2013). Although the motivational appeal of full-fledged games has already been discussed (Przybylski, Scott, and Ryan 2010), it is hard to pinpoint which individual game design patterns actually affect player motivation to behavioural changes, thereby only offering limited carry-over to gamification.

Gamification is assumed to engage people at an emotional level, which can be far more powerful than typical transactional engagement strategies. However, the inclusion of gamification technique – points, rewards, personalisation, data visualization, levelling up, status rewards, badges, peer obligation, social currency, missions and challenges – is still a new area with early signs of great potential for lifestyle improvements.

Here, I discuss the design opportunities and challenges of utilizing gamification approaches to encourage physical activity and promote motivations. Then, I demonstrated the inspirations and foundations of the *FitPet* mobile app, the prototype used in this study.

2.5.1. Design Opportunities and Challenges

Recent advances in small inexpensive sensors, low-power processing, and activity modelling have enabled new classes of technologies that use on-body sensing and machine learning to automatically infer people's activities throughout the day. Gamification approaches have been used together in order to promote motivational changes for a healthier lifestyle.

Gamification can play an important role in implementing change by defining a clear transformation path with simple steps and encouragement along the way. It usually adopts goal-setting, virtual rewards, and social features to help people change behaviours. Players can find kindred spirits and enlist the support of friends with social sharing. Gamification helps people repeat behaviours until they become habits, keep the process fresh, and develop change over time. Some of these emerging technologies and gamified mechanics have seen success with participants in research studies, such as controlled and "living" lab settings (Logan et al. 2007) and with researchers in situ (on-site, or in position) (Pentney et al., n.d.).

However, technologies that apply on-body sensing and activity inference to the fitness domain are faced with challenges regarding how to design effective gamified components as motivators, how to better engage people in an emotional level, and how to strategize social interaction for promoting and persistent effects. Moreover, lots of gamified elements still remain unidentified and in unevaluated states, whose application might shed light on more beneficial and effective methods for encouraging health behaviours.

2.5.2. Inspirations of the FitPet Mobile App: Tamagotchi

Therefore, to better answer my research questions – can certain gamification approaches effectively promote physical activity, and if individual can be motivated by associating their physical activity with a virtual-pet in an interactive mobile game, *FitPet* was designed with multiple game-based mechanics. *FitPet* is a virtual pet-keeping game which associates the pet's health and growth level with the users' activity level. Unlike *UbiFit Garden*, *Fish'n'Step*, or *Intro*, *FitPet* incorporates more game-based mechanics and dynamics, thus requiring a higher level of user interaction and engagement. The inspiration for such a virtual creature-keeping game comes from the popular use of mobile and wearable devices, as well as from *Tamagotchi*.

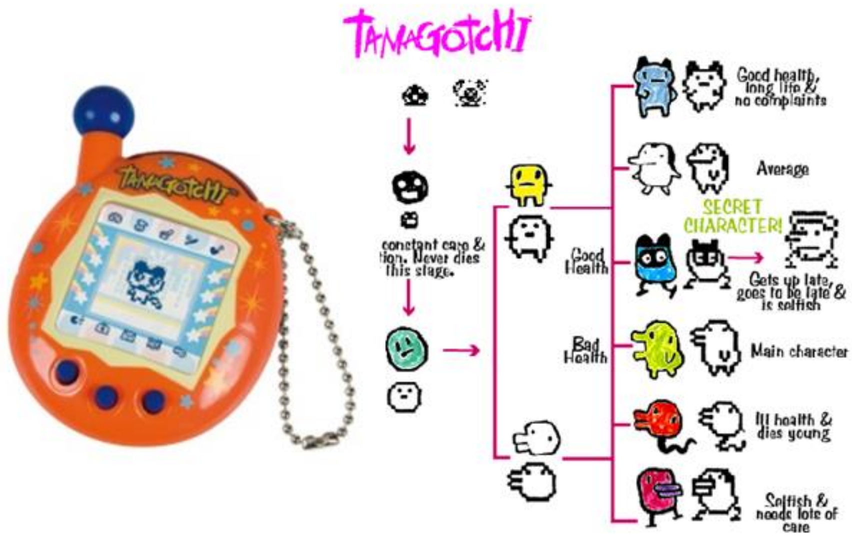


Figure 2.3 Tamagotchi Handhold Game Device and its Virtual Pets' Growth Conditions in the Device

Tamagotchi was first conceived by a Japanese mother for her children, since limited space precluded the introduction of an actual pet into the household (McMahon, 1997). It became popular in North America around 1997. In its popular days, both adults and kids all over the world they were obsessed with it. Once the game is turned on, the virtual animal is hatched from an egg and grows up. The plastic case with the small screen embedded in it can be worn as a bracelet/watch, suspended from the neck, or a key chain. In order to sustain it and maintain its health, the *Tamagotchi* requires virtual care, when necessary, in the form of sleep, a regular supply of food and drink, washing, play, teaching, scolding and medication. Its progress and needs can be assessed any time by pressing a button calling for a report which includes its weight, age, temperature, the extent of its hunger and thirst, mood and the like.

Similar gameplay was implemented into *FitPet*, in a more flexible way so as not to be intrusive and overwhelming for users to attend to the virtual pet.

Chapter 3.

Personal Informatics: Activity Data Visualization Design

In this chapter, I propose and design two different visualizations for activity data to be used in addition to the commercially used visualization methods. An overview of personal data analytics approaches and methods is provided. Furthermore, a user study was conducted in order to evaluate my visualization designs and the effectiveness of three visualizations. Finally, I discuss the visualization design implications for self-reflection and self-motivation purposes, and how I was inspired by the participants' feedback to develop the *FitPet* prototype used in the second user study. Experience and lessons learned from this study inspired me to explore the *FitPet* virtual pet-keeping game idea to foster individual long-term behaviour change.

3.1. The Designs of Personal Informatics Visualizations

Most of the commercial fitness trackers have a consumer interface that uses charts (mostly line, bars or pie charts) to represent the raw data. Various approaches have been designed and utilized by both industrial products and researchers based on geometric shapes, informative art and living metaphor, such as QS Spiral (Larsen et al. 2013), Spark (Chloe Fan 2012), the virtual flower (Consolvo et al. 2008) or the virtual pet-fish (Lin et al. 2006). They were developed to help people collect and analyze on personally data for purpose of self-reflection and goal achievement.

However, current tools for personal informatics and data analytics were not designed with sufficient understanding of a user's self-reflection needs. Most importantly, to verify people's opinion and get their feedback about the game-based virtual pet-keeping gamification mechanics, I conducted this research to better understand the effectiveness of the strengths and weaknesses of different visualizations.

People strive to obtain knowledge about their physical activity. Devices like *FitBit* are appearing that help people track and visualize their physical activity data. Visualizations are the main resource for individuals to formalize their understanding of their physical conditions, activity levels, and exercise goals, based on data from wearable trackers, and coupled with qualitative information. Visualization graphics, such as bar or line charts, have been normally adopted as the data visualization approach. However, it is difficult to fully demonstrate periodic or longitudinal data in order to show the continuous timescale as time goes by with these traditional representational approaches.

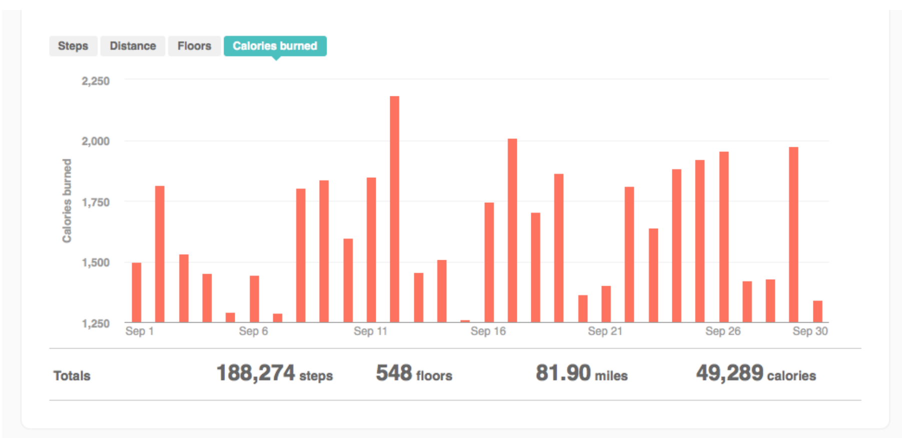
I explored three types of visualizations for personal activity data analytics: bar charts visualization from the *FitBit* Dashboard; my new circular ringmap visualization and my virtual pet ‘gamification’ visualization. The circular ringmap was designed to visualize time-series data in a circular structure, and the virtual pet approach was designed based on a gamification idea. In the study, I compared the effectiveness of three visualizations based on time spent on task, error rate, and participants’ self-reported post-test evaluation. The results showed that although pragmatic bar charts won on several attributes, the ringmap visualization demonstrated time dimension and helped users identify activity pattern easier. It also suggests that gamification idea has a good potential of being a motivator for maintaining physical goals and increasing the enjoyment and engagement with physical activity visualization.

In all three visualizations, one-month was chosen as the period of the user’s activity because it is neither too short nor too long. One month is a time scale that provides users with enough information for self-reflecting on their activity and finding possible patterns of physical activity. A day or a week contains less data for identifying a long-term activity pattern, whereas when the data covers more than three months or a year, it is too massive to be well-organized by the visualization structures used in this study. In addition, the data from longer periods of time is more difficult for participants to manage, from additional time scales (of, for example, comparing months) finding exact and small details.

3.1.1. *FitBit Dashboard Bar Charts Visualization*

FitBit has a commercial dashboard for its users to access their personal health data. Most of the personal data is displayed by bar charts (Figure 3.1). Users can switch to different data tabs in the dashboard such as steps, distance, floors or calories burned. The interface is interactive so that it can show the daily summary, and be adjusted to various time ranges or specific time periods. In Figure 3.1, the top image is one-month calories burned data; the bottom left is a weekly view, and right one shows one day's data.

Although such visualizations can provide users with a fundamental understanding about actual daily data and tendencies during certain time periods, it still lacks the presentation of an overview of regular daily patterns, long-term comparisons and representation of individual data. The reason I chose *FitBit* bar chart for experimental comparison was that such visualization were commonly and commercially used, so comparing my designs to it would tell us how pragmatic my designs are and what are the differences from commercialized visualizations.



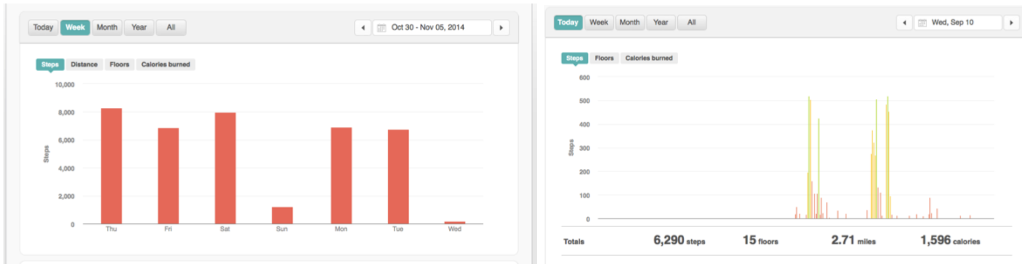


Figure 3.1 *FitBit* Dashboard Bar Chart Visualization (top: monthly view; bottom left: weekly report; bottom right: daily report including hours)

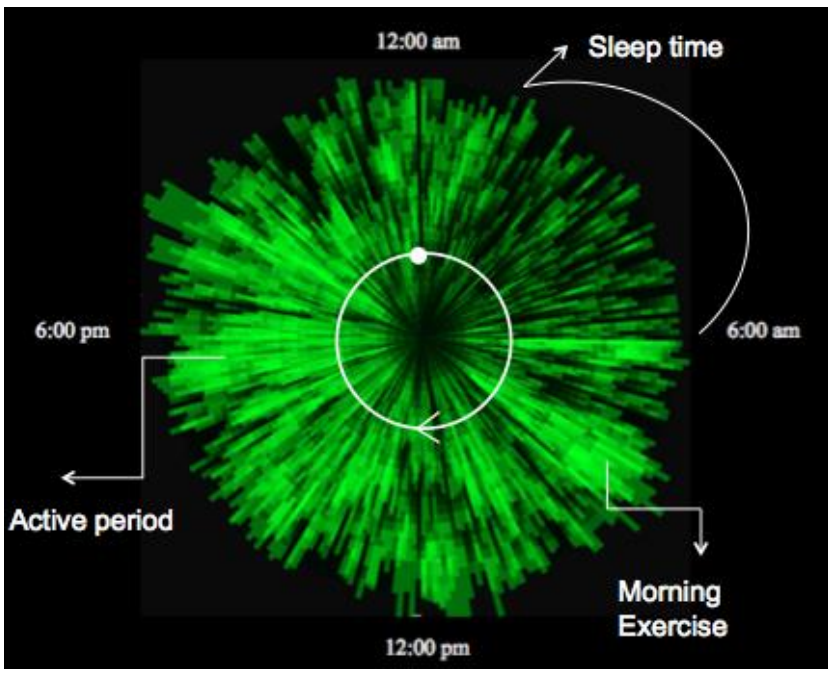
3.1.2. Life Cycle: Circular Ringmap Visualization

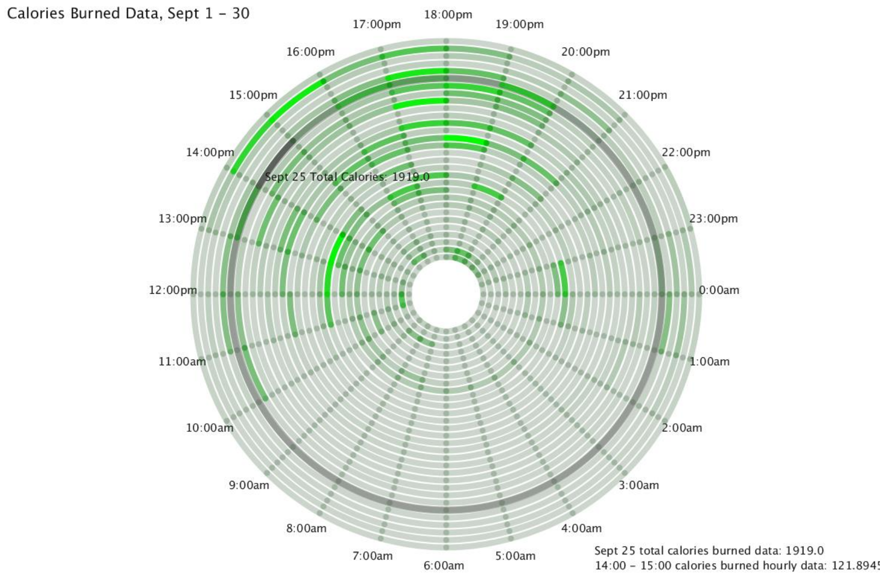
Since I would like to represent activity data within time scales – an abstract concept that is not inherently visual – I adopted a circular structure to represent flows and to trace and track variable processes of activity data (Figure 3.2). The visual aspect of this transformation of numerical to pictorial information makes the relationship between time and physical data easier to understand and remember. Therefore, the activity patterns, trends and tendencies are easier for users to understand.

This visualization simultaneously maintains the comparability of time and the integrity of the data set. The complexity of the data is in two dimensions, composed of both the data attributes and the time being recorded. I encoded the quantitative values in the color brightness. I also established a mapping route of position and time in this circular graphic.

In the top image of Figure 3.2, each ring represents a day, and starts at the top at 12:00 am. The time is arranged clockwise covering an entire day. The right is divided into equal slots of 5 minutes. I mapped the activity level with the brightness of the color in each slot, the brighter the slot, the more active was the user. As one would expect, the time between 12:00 am and roughly 9:00 am – typical time for sleep – is less bright. Most people move during sleep, but the data represented here suggests that 'quality sleep' inferred by the *FitBit* data only occurs from about 1:00 am to 4:00 am for most of the month. A strong sleep disturbance consistently appears at 6:00 am. The top image was original visualization that demonstrated my design concept. To increase its readability, I developed the second iteration (bottom left), and revised it to the final visualization (bottom right). The interactivity includes the possibility of varying the time span, allowing for different level of detail and discoverability of repetitive patterns in the data on multiple scales.

Through this visualization, users would be able to become aware and keep track of their long-term activity levels, and especially changes that occur over specific periods of time. To further assist users in developing a greater understanding of their physical activity, they can move the mouse or cursor over particular area to see specific information on certain date and time.





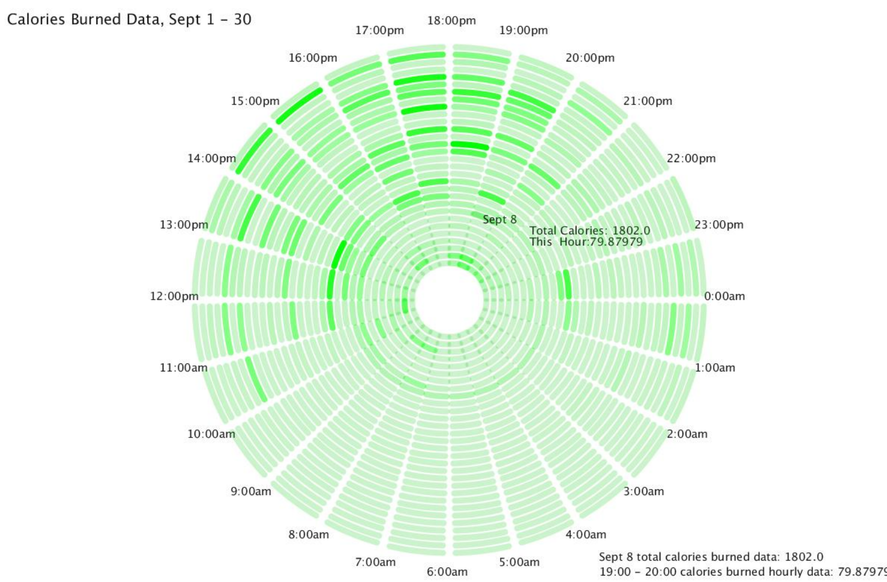


Figure 3.2 Circular Ringmap Visualization - *Life Cycle* (top: initial design concept; middle: second iteration; bottom: final design)

3.1.3. Virtual Pet Calendar View Visualization

To encourage users to track of their data regularly and keep them motivated we developed the virtual pet-keeping calendar visualization. I believe that users could be more motivated to work on their activity levels and physical conditions and reflect on their own activity data. It would also be better at distinguishing between gross changes in activity. Figure 3.3 shows the different physical conditions upon date in a calendar view. It categorized physical activity data into five levels: extra high, high, medium, low, and extra low. Then those categories were mapped it into the virtual pet's health condition and the virtual plant's growth.

The design of the virtual pet was inspired from the popular Japanese handheld digital pet – *Tamagotchi*, whose usage was analyzed by Higuchi et al. [15]. The actual five figures were designed by mapping approximate activity level to possible real life scenarios. Such like being a couch potato stands for a low level of activity, whereas being a super hero suggesting extremely high level of activity. The virtual plant visualization was built after I finished the whole study. From participants' feedback on the "individual design" question, and based on the *FitBit* flower application concept, the growth of a virtual plant was mapped to different levels of activity.

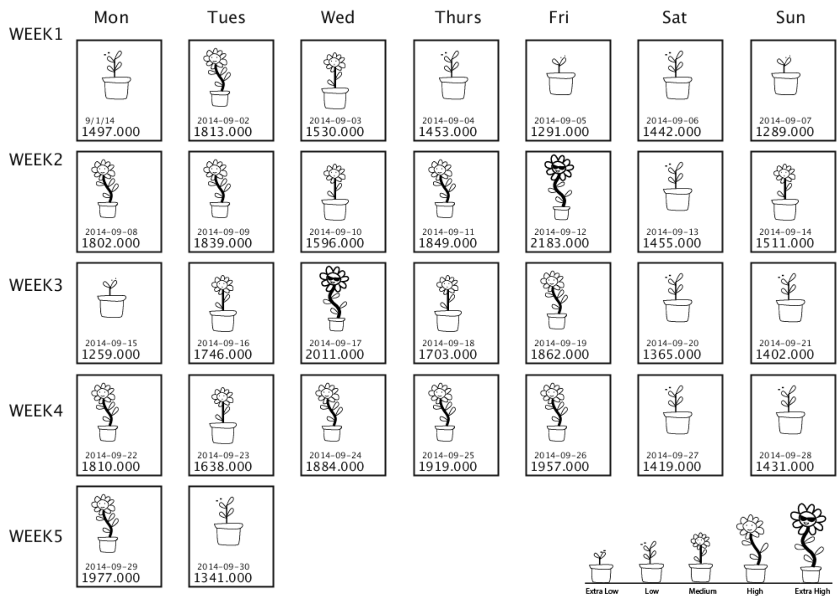


Figure 3.3 *Virtual Pet* Gamification Visualization (top: virtual pet visualization; bottom: virtual plant visualization)

3.2. Study Description

The goal of this study was to compare the effectiveness of *FitBit* Dashboard bar charts, *Life Cycle* circular ringmap, and virtual pet calendar visualization, and to understand how they influence users' self-reflection of daily activity. I measured users' performance on the task. Readability, comprehension, attractiveness, awareness, and empathy were evaluated to compare the effectiveness based on both performance and self-reported data. The explanations and definitions for each attribute in this context are:

Attributes	Definitions
Readability	To what extend the users could read the data presented in the visualization
Comprehension	To what extent users would understand what the visualization means, from the representation approaches (bars, rings, or figures) to identify

	different activity levels
Attractiveness	To what extend users are attracted by the graphic design (color, data organization methods and so on), the metaphors and the representation mapping approach of a visualization
Awareness	How easy or difficult the visualization is for the users to self-reflect on the activity conditions (to distinguish either the user has a high or low level of activity of certain time period) out of the data set, and to answer the questions
Empathy	Trigger an emotion or feeling because of the visual representation of the visualization

Table 3.1 Definitions of the Evaluation Attributes

3.2.1. Hypotheses

Since bar charts are commonly used in commercial health tracker applications and are frequently seen in daily life (the other two visualization approaches were designed by the author and never seen by the participants before the task), so I assume *FitBit* bar chart visualization will have the highest rank of readability and comprehension. Circular ringmap has two dimensions – date and hours, and users need to hover the mouse to specific location to track data, so it will take longer to complete task. As for awareness, circular ringmap will be rated first because its circular structure would be helpful to trace time changes. In terms of attractiveness and empathy, virtual pet visualization will be more attractive because it integrated gamification design with cartoon figures. Circular ringmap will be rated next because of its layout design and color brightness transition and contrast. Based on the analyses, I hypothesize:

1) H1: *FitBit* bar chart study group has a lower value of error rate and time spent on task than the other two.

2) H2: *FitBit* bar chart group will have the highest ratings of readability and comprehension, virtual pet group follows next.

3) H3: For awareness, the circular ringmap group will be rated first, and then virtual pet group.

4) H4: For attractiveness and empathy, virtual pet group ranks first, followed by circular ringmap group.

3.2.2. Participants

18 participants (8 males and 10 females, aged from 19 to 29) were recruited among university students. However, the distribution covered fairly large individual variations in their lifestyle and attitudes towards physical exercise based on the pre-test questionnaire. This spanned from individuals never having, nor wishing for an exercise routine, to individuals who exercised rigorously and regularly. Out of 18 participants, 8 (44%) had a regular routine of daily exercise (> 1 hour/day and > 5 days/week), 4 (22%) have exercise but not regularly nor for a long time (< 1 hour/day and > 3 days/week), and 6 (34%) people do not.

Convenience sampling was used to choose the participants. All experiments conducted under this study had ethics approval and participants were required to sign a consent form before the study. None of them are *FitBit* (and similar commercial products) users or used *FitBit* before, and none of them had seen any of the three visualizations in the study before.

3.2.3. Procedure

A quantitative experiment was conducted, which was measured between-groups. The same data set was used for presenting three visualizations. Between-groups experiment design avoids participants' learning effects across three visualizations and it saves experiment cost – time and expenses. The type of visualization (*FitBit* bar charts, circular ringmap and virtual pet visualizations) is the independent variable; the performance (time spent on task and error rates) and participants' self-reported post-test evaluation were dependent variables.

Three groups were created which were roughly matched on age and gender, and the same amounts of participants were assigned to each group. The study consists of 3 sections: pre-test, test and post-test. The data was collected from three questionnaires, one in each section. The whole procedure takes 20 – 25 minutes in total for each participant.

Pre-test: Before the test, a brief introduction about the experimental process was given to participants. Then they filled in a pre-questionnaire which aimed to understand their daily activity levels and to investigate if they were motivated by their activity data or self-reflect on the data.

Test: During the study, participants complete a task that consists of ten questions using one of the three visualizations, questions including range, compare, order, and exploration tasks. Time spent on each question, total questions and error rate were measured. Figure 3.4 shows the task interface that was used for performance measurement. Below are the main types of questions asked in the study test:

1) Identify the data's range of a certain day in a month (max and min values);

2) Identify the levels (out of five categories: extra high/high/medium/low/extra low) of a certain day in a month;

3) Identify if the activity level of a certain day or certain week is considered healthy (definition of healthy in this task: over half of the days in a month has an activity data that above average);

4) Explore the activity trend or pattern in the visualization and when it happens.

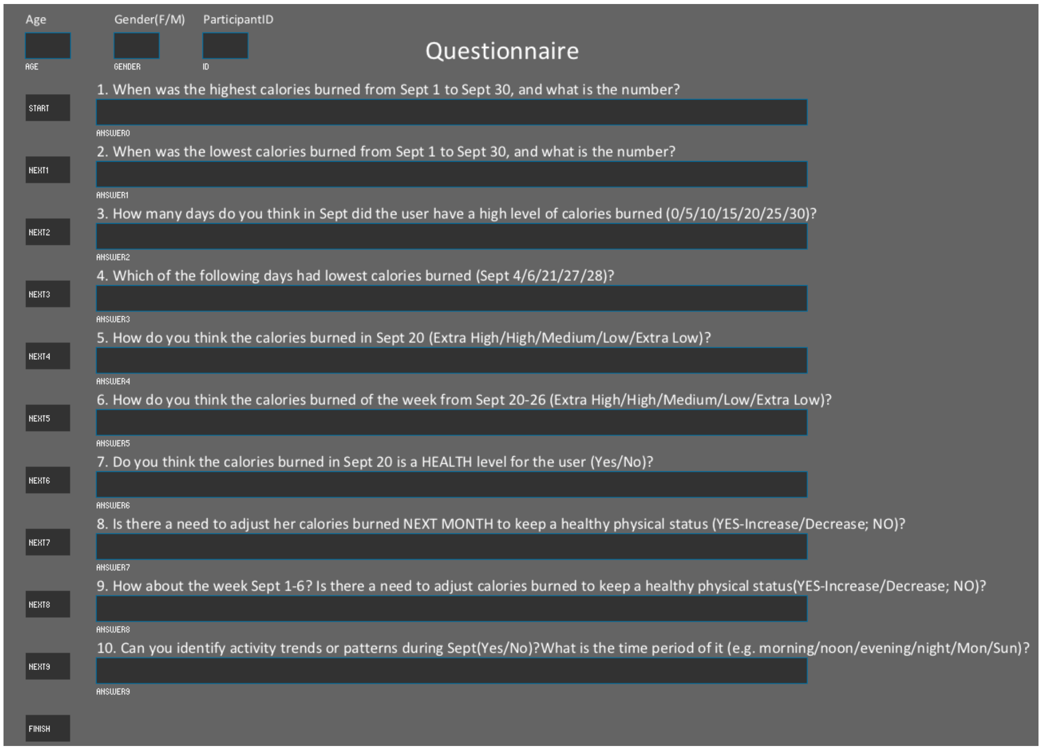


Figure 3.4 Performance Measurements and Interface During the Test Phase

Post-test: After the test, all three visualization were shown to the participants and they were allowed to interact with the other two for three minutes so that they could get an understanding about all visualizations. Then, the participants were asked to fill in a questionnaire evaluating the one that they were given in the task. For each attribute (readability, comprehension, attractiveness, awareness, and empathy), participants reported the degree of their experiences in a 7-scaled Likert Table from “not at all” (scored 0) to “very much” (scored 6).

	Pre-test	Test	Post-test	Participants
Group 1	Pre questionnaire	Task on *FitBit* dashboard bar chart	Post questionnaire	4 female, 2 male

Group 2	Pre questionnaire	Task on Circular Ringmap	Post questionnaire	3 female, 3 male
Group 3	Pre questionnaire	Task on Virtual Pet	Post questionnaire	3 female, 3 male

Table 3.2 Experimental Conditions: 3 Groups Tested with Three Visualizations

3.2.4. Results

In this section, descriptive analysis from the pre-test questionnaires, and inferential results from the task performances measure and post-test questionnaire are reported. The results demonstrate participants' physical activity level and their understanding towards activity, their actual performances in the task and how they self-evaluated certain visualization.

From the pre-test self-reported questionnaire, the degree to which participants reported that they pay attention to (think about and actually do something about physical activity) their physical activity is (M = 58%, SD = 24%). The degree to which participants reported that they understood their activity data is (M = 48%, SD = 16%). Out of 18 participants, 12 (67%) had regular daily activity exercise (> 1 hour), and 6 people do not. For the question "is there any motivation for you to maintain certain level of activity?" 3 said no specific reason to keep them maintain a certain level of activity and they never thought about it; 9 said they would like to keep a general healthy physical status and enjoy the experience of being active; and 6 had specific fitness goals like weight control, keep a good form or build muscles. Overall, I concluded that most of the participants pay attention to their daily activity situation and most have an average understanding about their activity levels. 2/3 of the participants keep regular exercise.

The inferential analysis of the one-way independent ANOVA was run to examine if the independent variable – visualization types – had significant different influences over participants' task performances and their effectiveness ratings.

Task Performance Comparisons Mean(M)/Mean(SD)	Time spent on task (minutes)	Error rate (%)
FitBit Bar Chart	8.17(2.43)	13(13)
Circular Ringmap	7.89(.88)	23(15)
Virtual Pet	7.77(.22)	10(10)

Table 3.3 One-way independent ANOVA of Total Task Performance of *FitBit* Bar Chart, Circular Ringmap, and Virtual Pet Visualizations (* indicates significance at p< .05 level; ** indicates significance at p< .01 level)

For the three groups, as shown in Table 3.3 (also in Figure 3.5 and figure 3.6), the time spent on task (minutes) of *FitBit* bar chart (M = 8.17, SD = 2.43), Circular Ringmap (M =7.89, SD = .88), and Virtual Pet (M = 7.77, SD = .22) groups did not have significant differences, $F(2, 17) = .04$, $p = .96$. The error rate of *FitBit* bar chart (M = .13, SD = .13), Circular Ringmap (M = .23, SD = .15), and Virtual Pet (M = .10, SD = .10) groups also did not have significant difference, $F(2, 17) = .89$, $p = .46$. It indicated that the performances of three groups on the task did not have significant differences.

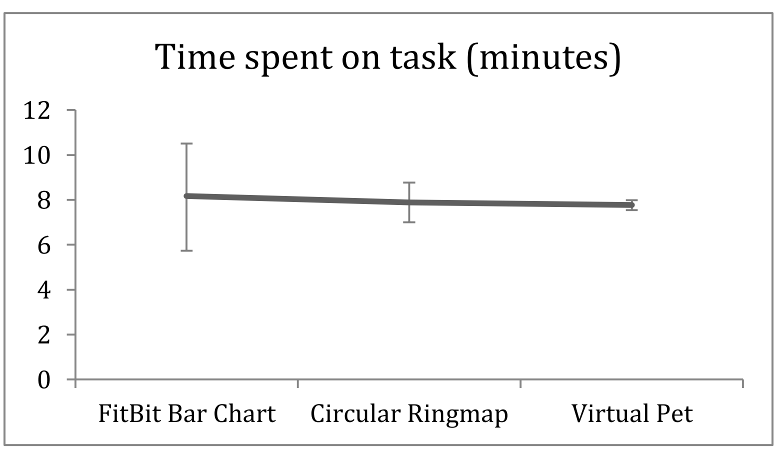


Figure 3.5 The Mean and SD of Three Groups: Time Spent on Task (mins)

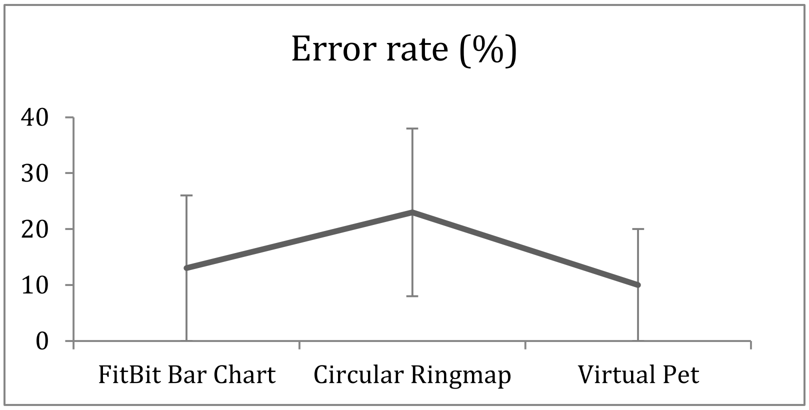


Figure 3.6 The Mean and SD Value of Three Groups: Error Rate (%)

For the post-test self-reported evaluation, there were strong significant differences found in readability, $F(2, 17) = 14.02$, $p < .01$, and empathy $F(2, 17) = 7.61$, $p < .01$ among three visualizations. General significant differences exist in the ratings of awareness, $F(2, 17) = 5.86$, $p < .05$, and comprehension, $F(2, 17) = 5.07$, $p < .05$. However, no significant difference appears among all in terms of attractiveness, $F(2, 17) = .02$, $p = .98$. Mean and SD values are shown in Table 3.4 (Figure 3.7 and Figure 3.8).

Self-reported evaluation Mean (SD)	Readability	Comprehension	Attractiveness	Awareness	Empathy
FitBit bar chart	5.83**(.41)	5.67*(.52)	4.5(1.87)	5.67*(.52)	1.33**(1.51)
Circular ringmap	2.83**(1.17)	3.33*(1.75)	4.67(1.03)	3.67*(1.51)	2.50*(1.87)

Virtual pet	4.17*(1.17)	4.50(1.22)	4.67(1.51)	4.83(.75)	4.50**(.55)

Table 3.4 One-way independent ANOVA of Task Performances (* indicates significance at p< .05 level; ** indicates strong **significance at p< .01 level)**

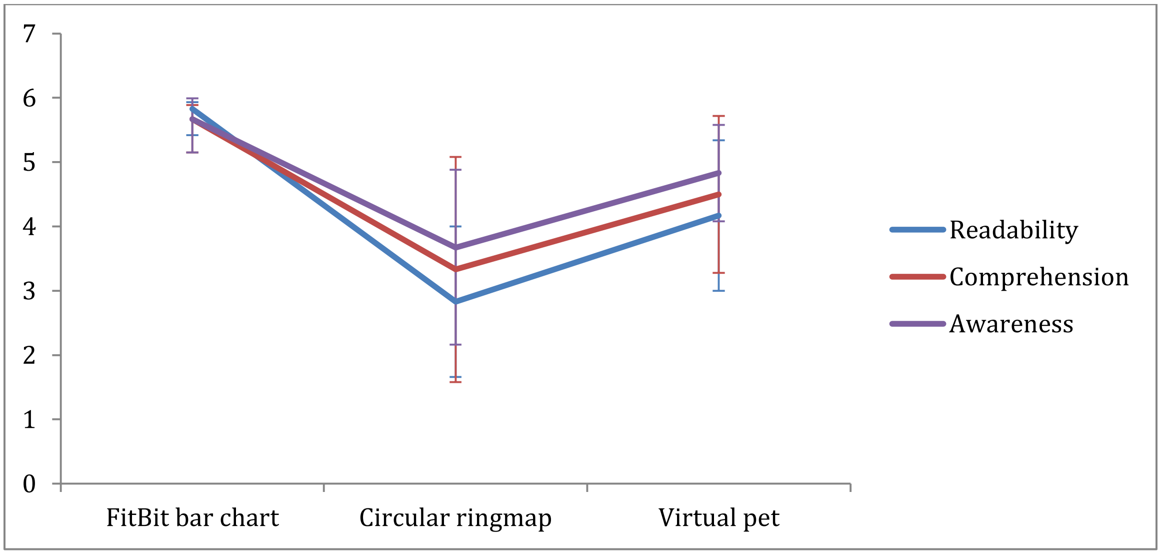


Figure 3.7 The Self-reported Evaluations from three Groups: Readability, Comprehension, and Awareness

For the attributes with significant differences, Tukey-HSD tests were run to figure out exactly which pairs have significant differences. From comparisons for all pairs, *FitBit* bar chart and circular ringmap had a significant difference in Comprehension, and Awareness. Virtual pet had a strong significant difference comparing with *FitBit* bar chart in Empathy, and it had a significant difference comparing to the circular ringmap visualization. For Readability, there were significant differences among all three – *FitBit* bar chart had a strong significant difference from both circular ringmap and virtual pet visualizations; circular ringmap and virtual pet visualizations also had a significant difference.

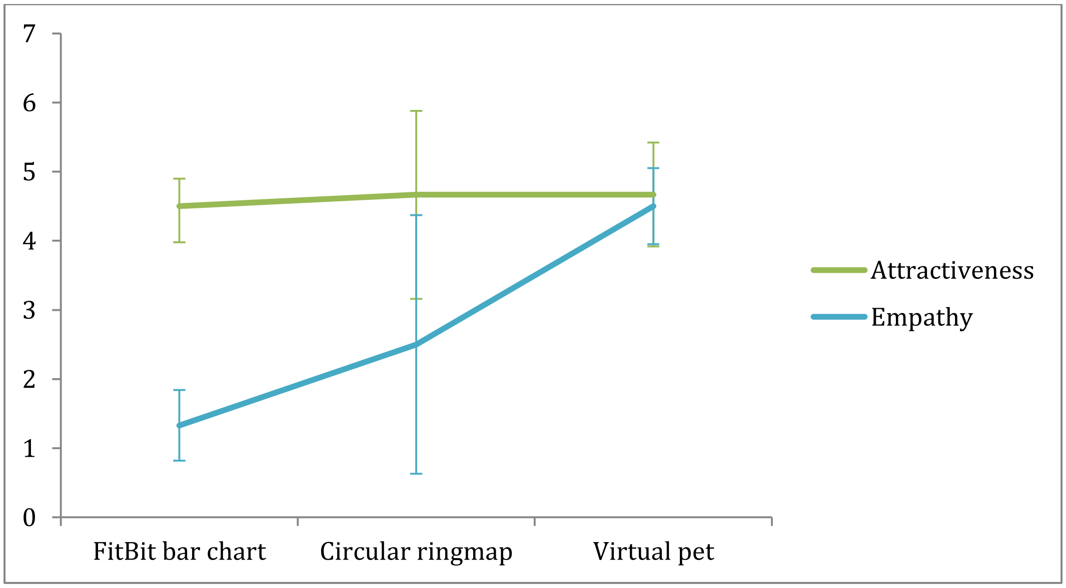


Figure 3.8 The Self-reported Evaluations from three Groups: Attractiveness and Empathy

From the results of this study, non-significant differences of task performance were found among the three visualization groups. Interestingly, the self-reported evaluations regarding visualization attributes from the post-test questionnaires tell us a different story. Participants perceived the bar chart to be the most readable, comprehensive, and aware one. The ringmap visualization ranked last of all three. Although virtual pet was rated in the middle, there were no differences between it and the bar chart for comprehension and awareness. For empathy, strong effects were found between virtual pet and bar chart, and between virtual pet and ringmap.

Although objectively speaking, three groups achieved the same task performance, which indicated that people should not see a difference across three visualizations. However, subjectively, participants did perceive the five attributes of the visualizations differently, especially for readability and empathy attributes. It can be concluded that the ringmap visualization structure was not helpful or intuitive enough for the participants to reinterpret. It is unclear whether the novelty of the visualization format played a part in the results. In comparison, the virtual pet visualization was considered to be the visualization that evoked the most empathy. The Empathy matters in this study, because it tells us there is a relationship between the visualization and the users' emotion.

As for the open question about customized visualization design, participants gave lots of valuable design suggestions and feedback towards the visualizations. For *FitBit* bar charts, P1 suggested that “I would use more colors for visualizing the bars, and the color selection depending on how well I worked out and what was accomplished. For example, use different shades or tints of red that explains intensities of work out and different colors settings for what kinds of activities, like gym, jogging, or bike.” P2 wrote, “Maybe switch to line charts instead of bar charts since line charts has the metaphor like mountains, and it is easier to follow trends.” P15 also gave the same feedback as P1 and P2 – she reported, “I think there can be a line chart showing the long-run activity trend so that it is clearer. It would also be better if bars were color-coded (just like circular visualization, using color brightness to represent activity level).” Not much individual design or suggestions was made for the circular ringmap, only P8 reported, “I would design my visualization somewhat like circular structure visualization; however, it needs to be more simple and have a legend so that no explanation is needed.” As for virtual pet visualization, P18 suggested, “I might design a plant instead of pet and use the growth of virtual plant to stand for activity level”. P16 reported, “I would have the same idea and design a virtual pet-keeping visualization, but change the images that are very alike (medium and high activity level figures in the test were confusing)”.

3.3. Discussion

In this section, the strengths and limitations of this study are listed. Critiques and reflections of *FitBit* bar chart and my designs – circular ringmap and virtual pet visualizations are discussed in depth. Finally, future work is proposed in terms of the visualization design and the next user study.

3.3.1. Interpretation of Study Results

From the results, I discovered that there is no significant difference of total task performance (time spent and error rate) among the three visualizations.

The results did not support hypothesis H1. However, I think this is due to wide types of questions included in the test, where certain type of visualizations can be more easily answered with one visualization over another. For example, participants in circular ringmap group and virtual pet group spent less time on the last question and had a lower error rate with strong significant differences from the *FitBit* bar chart group, when they were asked to identify activity patterns from a month data. Therefore, I conclude that the circular layout of time and data helped participants identify periodic patterns. In addition, it's the combination of angle and color that allows one to explore the patterns of activity events. The virtual pet has a calendar layout and classifies activity levels into five categories. The ordinal cartoon figures and calendar interface design facilitated the exploration of data patterns and trends. Furthermore, in the 3rd question, which asked participants to summarize day counts of a certain activity level through the whole month, there was a significant difference on error rate. Circular Ringmap group spent more time and had a higher error rate than the other two groups. The results indicated circular structure made counting days (aggregating days) difficult for users.

In the post-questionnaire evaluation, the results of Readability and Comprehension supported hypotheses H2. Although all three had similar values of task performance measurements, participants had a more positive experience towards *FitBit* bar chart than virtual pet and circular ringmap in terms of Readability and Comprehension.

Participants rated a higher value of Empathy on Virtual Pet than *FitBit* bar chart, which corresponds to hypothesis H4. I conjectured that the pet character can provide positive reinforcements for the participants and they can relate the physical conditions and wellbeing of the virtual figure to their own activities and wellness. So it provides a potential for motivating real world behavior changes, for instance, positive reinforcement to a desired level of activity and negative reinforcement to a lack of activity.

In general, the circular ringmap and virtual pet visualizations served their purposes: to represent activity patterns or trends so that help users better understand the physical activity conditions of the visualizations.

3.3.2. Study Critiques and Design Reflections

The aim of using *FitBit* dashboard is to compare my designs with a visualization that is already commonly used, with my designs. Specific features were incorporated in our design for users to allow users to better understand personal data. From the questions in the post-questionnaires, I received inspirations for designing better visualizations. Furthermore, the results from task performance and post-questionnaire ratings showed implications for future personal informatics design. Therefore, I proposed below four design inspirations and implications.

1) Visualize a large-scale of data available and show them in an organized way. To make quantified personal health data more beneficial for self-reflection, a large volume of data needs to be easily accessible, so that the patterns, trends and progress can be monitored. In the circular ringmap, data were organized in a circular structure which showed long-term patterns; in virtual pet visualization, the real physical progress was represented by the visual figures of a pet with corresponded behaviors.

2) Combine different types of visualizations together. More than one type of visualizations combined together will be able to represent the data in a more meaningful way, and it will increase users' engagement with the data over time. Participants suggested combining two types of visualizations together. One suggested to use bar or line graphs for establishing initial awareness, which allowed users to search for specific information, and combine this with the circular ringmap for reflecting on activity patterns. Another, however, said to combine bars with the virtual pet so that it could provide both accurate info and more engagement and enjoyment.

3) More visual design elements should be involved in representing data. Instead of prescribing one number or range with a bar's height, the visualization could use the transparency, brightness, or hue as the circular ringmap, and the shape, color, or figures design as the virtual pet.

4) In *FitBit*-like bar chart, incorporate design metaphors into activity levels visualization. For the current *FitBit* bar charts visualization, new interactions should be built in order to provide a faster exploration of activity patterns in a long-term and large-scale data set. Color-coded mechanism for representing different levels of activity intensities is also recommended, because it could benefit the users to identify and count active/inactive days more easily (currently, *FitBit* dashboard offered color-coded bars only on hourly-level, not for every graph). Besides bar charts, line chart could also be implemented as user-expected goals in the background so that when users could also feel “empathy” (negative or positive reinforcements by comparing reality with expected activity levels or goals).

3.3.3. Study Limitations

In the first user study, limitations in visualization design, experimental design, and data collection can impact the results. Below I discussed the limitations of the study.

The participants were all university students aged from 20 – 30 years old. They can accept and adapt new technologies or new interfaces faster and easier than elders. Also their daily schedules are more flexible than workers or office staff. Those factors might cause a different choice of post-questionnaire evaluation, and answers to design recommendations and opinions. Familiarity with *FitBit* or similar health tracker is another factor. None of the participants have used *FitBit* before. However, people who are familiar with commercial visualization approaches might give more in-depth feedback since they spend longer than others tracking their personal data.

In the between-subject study, each participant only tried one type of visualizations. If choosing different data sets at the same difficulty level and switched the study to within subjects, participants could have experienced all three visualizations. Furthermore, there should be more subjects for all three groups.

Finally, the data that selected were calories burned in a month from a regular anonymous *FitBit* user. Other types of data sets, such like sleep, steps, and active time from more *FitBit* users, might inspire more insights from the participants.

Chapter 4.

The Game-based Approach for Encouraging Steps: '*FitPet*'

In this chapter, the design principles and development procedures of *FitPet* is introduced. It is a mobile application that combines ubiquity and simplicity of mobile devices with the engagement of computing games, intended to motivate people to incorporate more walking into their daily routine. *FitPet* was created for research purpose, aimed at creating a systematic evaluation of quantified and gamified presentation of activity-related data by implementing game mechanics and dynamics. Therefore, the prototype was developed with main features including goal-setting, health data-coin conversion, and user-pet interaction, pet health and growth changes. Besides, step capture algorithm was demonstrated and its step-detection accuracy was evaluated.

4.1. Steps Capture

FitPet was built as a research prototype and a mobile application that is available to be used in both Android and IOS platforms. The goal of this research prototype is to provide a non-intrusive and gamified system that can be deployed in a user's daily routine. Step is selected as the parameter to assess users' overall activity level. Therefore, the mobile phone's accelerometer is used to measure users' movement. The users only need to open the software when they have active physical activity to get more steps.

The walking detection algorithm samples the 3-aixes accelerometer 60 times per second. From the characteristics that can be used to analyze running or walking, acceleration is chosen as the relevant parameter. The three components of motion for an individual (and their related axes) are forward (roll), vertical (yaw), and side (pitch). Since the mobile phone's accelerometer will be in an unknown orientation, the measurement accuracy should not depend critically on the relationship between the motion axes and the accelerometer's measurement axes.

To detect and calculate steps data, first the definition of a step needs to be clear. Figure 4 illustrates a single step, which is a unit cycle of walking behaviour, showing the relationship between each stage of the walking cycle and the change in vertical and forward acceleration. Step definition and detection algorithms in pedometer and mobile devices have been tested and evaluated in prior research (Zhao 2010) (Ali and George 2012) (Terra et al. 2013). Therefore, in *FitPet*, I referred to Zhao et al.'s algorithm. At least one axis will have relatively large periodic acceleration changes, no matter how the mobile phone is placed, so peak detection and a dynamic threshold-decision algorithm for acceleration on all three axes are essential for detecting a unit cycle of walking or running.

Built upon prior research about the pedometer sensor algorithms, *FitPet* step detection continuously updates the maximum and minimum values of the 3-axis acceleration every 60 samples. The average value, *(Max+Min)/2*, is defined as the *dynamic threshold level*. For the following 60 samples, this threshold level is used to decide whether steps have been taken. The step counter calculates the steps from the x-axis, y-axis, or z-axis, depending on which axis' acceleration change is the largest one. If the changes in the acceleration are too small, the step counter will discard them.

The step counter can work well by using this algorithm, but sometimes it seems too sensitive. When the pedometer vibrates very rapidly or very slowly from a cause other than walking or running, the step counter will also take it as a step. Therefore, *time window* and *count regulation* are used to solve this problem in order to discard invalid vibrations.

Time window is used to discard the invalid vibrations. I assume that users can run as rapidly as five steps per second and walk as slowly as one step every two seconds. Thus the interval between two valid steps is defined as being in the time window [0.2s to 2.0s]. All steps with intervals outside the time window should be discarded.

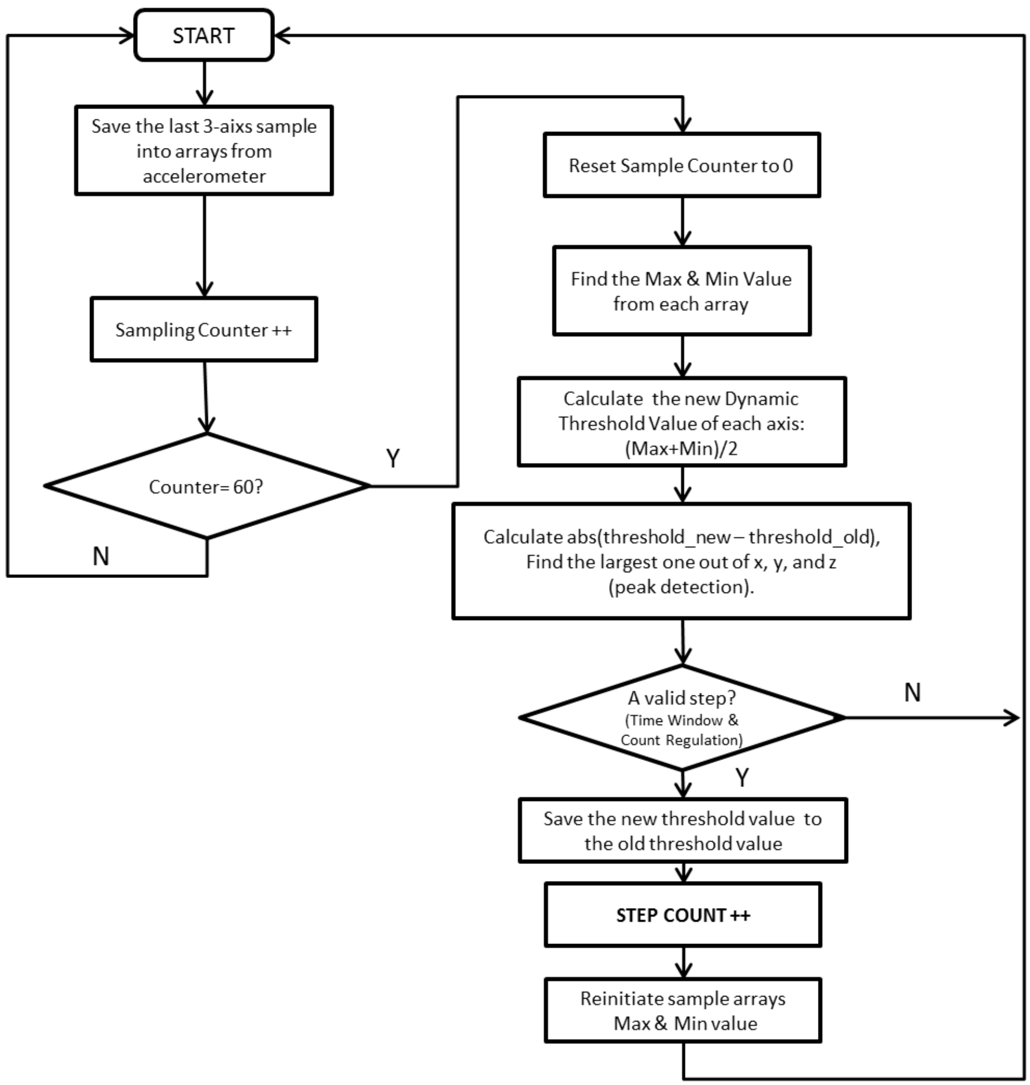


Figure 4.1 Flowchart of the Steps Parameter Algorithm

Count regulation determines whether steps are part of a rhythmic pattern. The step counter has two working states: searching regulation and found regulation mode. Suppose that in regulation exists after four continuous valid steps. Then the result is refreshed and displayed, and the step counter will work in found regulation mode. Working in this mode, the step counter will be refreshed after every valid step. But if one invalid step is found, the step counter will return to searching-regulation mode and search for four continuous valid steps. Figure 4.1 shows the flowchart for the steps parameter.

The reliability of this step counter algorithm in mobile phone was evaluated and compared with the step data collected by *FitBit* device. The average level of detection accuracy comparing to *FitBit* was around 110-120% while running or walking (shown in Table 4.1). Both the mobile application and *FitBit* wearable health tracker are not as accurate when biking, sitting, and driving as when walking or running. The reason is that they both rely on the movement of the devices itself, whose motion does not necessarily mean the users' movement changes. For example, no steps should be computed while sitting or driving, but both of *FitBit* and *FitPet* display a few steps. It might be caused by the occasional movement of one's arm or the changed direction of the mobile phone placement.

Activity	Steps measured by *FitBit* in 10 minutes	Steps measured by *FitPet*	*FitPet* detection compared to *FitBit* (%)
Walking	1898	2126	112.01
Running	3102	3536	114.0
Sitting	12	21	175.0
Driving	26	19	73.07

Table 4.1 Steps Measured by *FitPet* and *FitBit* in Various Activities

4.2. Design Principles: Focusing on Users' Goal and Experience

The tools of gamification can be a powerful means to motivate people to achieve their goals. In this section, design principles summarized from prior research and literature reviews were adopted for the *FitPet* design, including *Player-Centric Design*, *Give Meaning to Users*, and the *Bottom-up Design Method*.

4.2.1. Player-Centric Design: Creating Enjoyable and Playful Experiences

Gamification experiences (player experience) are personal encounters that occur over a period of time and can deeply impact individual's perceptions, build knowledge, and direct people's actions (Burke 2014). In a gamified solution, the player experience is designed as a 'journey' and takes place in a play space that may encompass both the physical and virtual worlds.

Player-centric design is a design method usually used for game and gamification design. Burke (Burke 2014) argues that it starts with an understanding of the player's goals and ambitions and strives for an experience that engages players at an emotional level to help them achieve a goal that is meaningful to them. It focuses on achieving player goals and reduces both the time and the risks of designing a gamified solution.

Therefore, in *FitPet*, goal-setting is the key for designing and playing this virtual pet-keeping game. The relationship between goal-setting and virtual creature's wellness and evolvement is the core mechanics that incorporate the users' daily physical activity goal into the wellbeing of their virtual pet. The tight connection is designed for player engagement so that during the 'user-pet interaction', users will grow emotional attachment to their virtual pet. *FitPet* also asks its users to break larger goals (like a long-term fitness or activity goal) into smaller practical challenges – a daily steps goal. This is to encourage players to stay motivated through the growth progress of their virtual pet and engages them *emotionally* to achieve their best to attend to the virtual pet.

4.2.2. Give Meaning and Purpose to Players

According to *Gamify* (Burke 2014), gamification is not simply about "slapping points and badges onto an activity and expecting it to magically become more engaging.

It is about understanding the players' goals and motivations and designing an experience that inspires them to achieve their goals."

Therefore, *meaning* is the crucial aspect of engaging user gamification (Deterding, S 2011). An activity may be framed as meaningful, when embedded within a narrative, supporting user's personal goal and interests, or having a purpose that is deemed valuable by users. McGonigal states that meaning forms a type of intrinsic reward in itself, because "we want to belong to and contribute to something that has lasting significance beyond our own individual lives." (McGonigal 2011)

The term *Game with a Purpose* (GWAP) explained the use of game elements to make individuals complete tasks. In prior research, studies show that users preferred "gamified approaches" of solutions compared to non-game conditions. For instance, researchers (Goh and Lee 2011) found that more participants reported that they liked the gamified version of an image tagging task over a non-game version, even though the latter one has higher quality tags. In Mekler et al.'s research (Mekler et al. 2013), the effect of points and meaning framing were examined. The results implied that while points did motivate participants to generate more tags, a meaningful frame inspired them to do better at the task and create more quality tags.

In order to promote players' participation, tasks need to be imbued with meaning. Creating a gamified solution that engages people at an emotional level requires the understanding of players. Therefore, in *FitPet*, real-time steps feedback are provided and converted to game coins, so players could use the coins to play and interact with their pet. Users have the flexibly to choose what they want to do in *FitPet*. Furthermore, user's goal completeness is associated with the growth and general health of the virtual pet. Therefore, in *FitPet*, the assumption is that the users will gain meaning with *FitPet* because of their higher level of engagement and empathy with the virtual pet.

4.2.3. Apply Design Thinking: Bottom-up Method

Gamified experience design must build solutions from the bottom up by employing a process called design thinking. According to Tim Brown, "Design thinking is a human-centered approach to innovation that draws from the designer's tool kit to integrate the needs of people, the possibilities of technology, and requirements for business success.” (Brown 2008) The principles of design thinking can be applied to a broad range of problems and can augment conventional problem solving approaches. It is also applicable for gamified experience.

In software development, one of the most common problem-solving approaches is decomposition. Decomposition takes a big problem and breaks it down into much smaller individual problems that can be solved (Burke 2014). It then aggregates the small solutions into a larger solution to address a larger problem. While this approach is appropriate for many complex software problems, it is not the best for designing gamified experience. This approach addresses the obvious user requirements, but it typically does not consider user engagement and motivation.

When applies to gamification, likewise, it must start with the player-centric approach. In the design procedure, first, the goals and motivations of the potential *FitPet* players are explored before considering how to deploy solutions. Second, the first user study was conducted to recognize individual’s thoughts and feedback on associating health data with a virtual pet-keeping visualization to fully understand if they could understand and possibly accept such a game idea. Next, after learning the feedback of the ‘pet-activity representation’ idea from the first user study, iterations of the gameplay design were generated and then finalized before final development. Finally, game mechanics and dynamics were implemented to the gamified solution to engage players at an emotional level.

4.3. Developing Incentives and Providing Motivation

In order to motivate users to engage with the pet more frequently, and grow an emotional attachment to the pet, individual’s daily progress towards their goals was mapped to the development of the virtual pet in two ways. Firstly, the daily step count can be converted to game coins, and then the users can use their coins to play with their pets, feed their pets, and provide medical help when the pet is sick. Secondly, the growth level of this virtual pet is related to the accumulated total steps and the users’ daily step goal. The general idea of this mobile application is to take care of the pets by taking care of the player himself. Title screen is shown in Figure 4.2.

Figure 4.2 *FitPet* Title Screen

The step-coin game economics (dynamics), growth level and goal rule (mechanics), and visual design (aesthetics) are the key mechanics and dynamics implemented to encourage more engagement from the users with their virtual pets. I also adopted the acrylic painting user interface to differentiate it from traditional *Tamagotchi*-type (generally pixel style) games or mobile pet keeping games, and try to inspire more emotional responses to their virtual pet from the users.

4.3.1. Mechanics and Dynamics: Goals, Steps, Coins, and Levels

In addition to the detection of walking, *FitPet* also supports real-time feedback on performance and goal setting (Figure 4.3). The user can name the pet, and set up a daily step goal. It is designed as adjustable goals, so users can change the goals upon their needs.

Figure 4.3 Goal-setting and Name the Pet Functions Screen

Figure 4.4 Steps Data Record Screen

The step data is collected by the mobile phone's accelerometer and is displayed real-time in *FitPet* (Figure 4.4). Each time the user launches *FitPet*, new steps will be calculated and game coins can be gained when the users save their game progress. Updated steps will be converted to game coins automatically in the ratio of 30 steps to 1 game coin.

Core Mechanic and Representation: To keep the virtual pet stay healthy, the users need to increase the pet's Health Point (HP). When HP is higher than 50% of the overall health progress bar, the pet will stay healthy. If below 50%, the pet will be sick. The virtual pet's sick and healthy visual appearances are shown in Figure 4.5. Figure 4.6 shows the sick pet when not attended by the user and Figure 4.7 shows the healthy pet when it is well cared and has a HP higher than 50%. The HP will automatically be damaged and decreased by 20% every day until 0. However, the virtual pet will never die. Certain actions need to be done when HP is at certain level:

(1) When HP>=0 and HP < 10%, only medical help will save the pet;

(2) When HP>= 10% and HP < 80%, only food will have the effect of increasing the HP value and bring the pet to healthy state;

(3) When HP>=80%, only playing a mini game will increase the HP value.

Micro View Goals and Macro View Challenge: There are four growth levels in total, which were specifically designed for the experimental study. The daily goal completeness and accumulated total steps decides which level the virtual pet will be. As soon as the total number of accumulated steps exceeds a predefined value, the pet's visual appearance will change to the next growth level. Four levels are designed and deployed in *FitPet*. The level growth mechanism is designed for the six weeks study period only. When the user meets his/her daily goal, a particle firework animation appears in the screen to help cheer up the users, as shown in Figure 4.8. The level growth and steps relationship are as shown in Figure 4.5:

(1) Level One: total step <= 4* user's goal (goal is step number per day);

(2) Level Two: 4* user's goal < total step <= 8* user's goal;

(3) Level Three: 8* user's goal < total step <= 12* user's goal;

(4) Level Four: total step > 12* user's goal.

Figure 4.5 Virtual Pet Visual Design, Growth Levels and Step-growth Relationship

Figure 4.6 Sick Virtual Pet if not Well-Cared for

Figure 4.7 Healthy Pet if Well-Attended

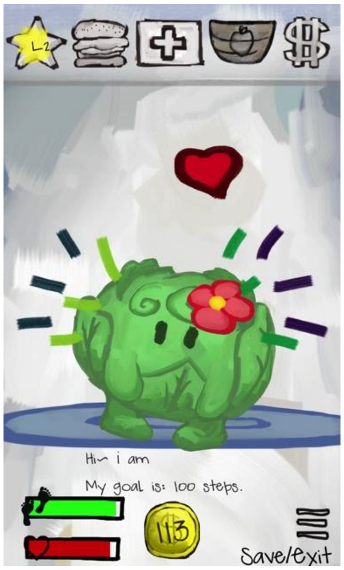


Figure 4.8 Happy Particle Animation Screenshot when Meeting Daily Goals

4.3.2. Cultivating Internal Locus of Control through the Care of Virtual Pets and Plants

There are various techniques developed to motivate behaviour changes. Traditional techniques are usually delivered by trained specialists. Such like goal-setting, self-assessment or the monitor of achieved progress. The approaches adopted in *FitPet* include motivating behaviour changes and increasing awareness by cultivating a strong locus of control through the care of a virtual pet, incorporating goal-setting task and real-time progress feedback.

Such interventions can benefit users from various aspects. First, the *FitPet* mobile application can be accessed and delivered anytime and anywhere as a cost-efficient way of tracking activities. Also, it provides users with a mapped representation of their physical activity data (steps). This mapping method has the potential impact over users' engagement and emotional aspects. The virtual pet's health condition can imply motivational messages to its users at the time of decision making, inspiring individuals to take simple steps to improve their health and encourage more physical activity. Moreover, an attractive and animated character together with the goal-growth game mechanics, tightly associates individual's goal completeness with the growth level of the virtual creature. Thus the users would feel a sense of obligation and mission to keep the virtual pet growing up in a healthy condition, which could be seen as the users' progress towards more active and healthy life style as well.

4.3.3. Designing for Emotional Engagement and Fun

In order to create a playful and engaging gameplay of *FitPet*, various game dynamics and mechanics are implemented and different things can be done within the game. Multiple options are designed for each interaction, such as feeding food, providing first aid, and playing the mini game.

The virtual pet will generate a thought bubble to users, indicating how to increase its HP value to keep healthy. The plate symbol implies the pet is hungry. The skull shows the virtual pet is dying and desperate for medical help. A hand appears in the game when the pet wants more interaction with the users. Thought bubbles are shown in Figure 4.9.

Figure 4.9 Thought Bubbles of the *FitPet* – Food, Play, and Medical Help

Various food and first aids aim at enriching users' options depending on the game coins they transferred from their physical steps. Each has a different cost and also a different HP value. Thus, users can make plan and strategize how they are going to deal with the money. As depicted in Figure 4.10, food collections include sushi, cake, green salad, and sandwiches. First aids box contains pills, injection and infusion, representing various degree of healing power to the virtual pet.

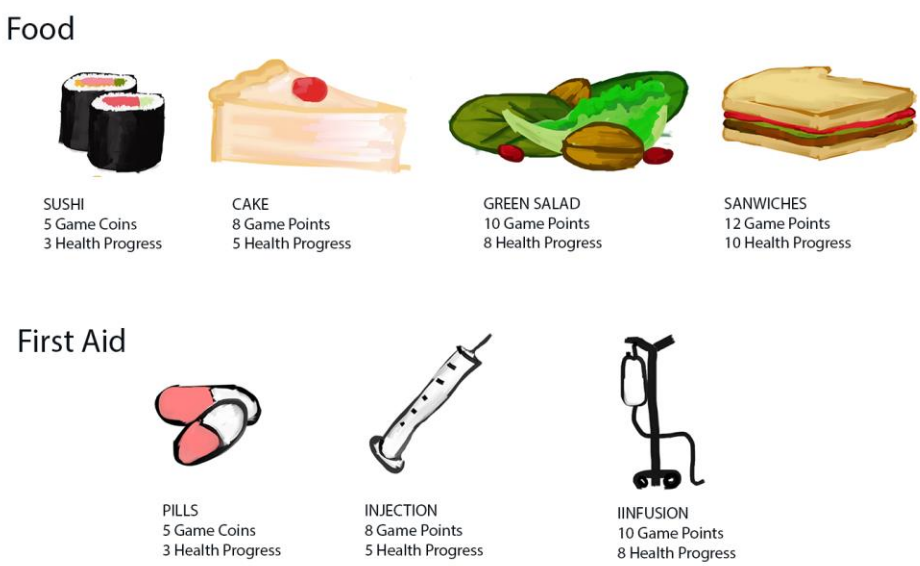


Figure 4.10 Options of Food and First Aid for *FitPet*

A mini catch game is incorporated into the virtual pet keeping game in order to increase the level of playfulness and fun. Since feeding and medical help are simple interaction, it can become a repetitious experience over time. Therefore, a mini-game is designed for better engagement within *FitPet.* In this game, users could control the virtual pet's physical location on the mobile screen and catch fruits to gain more points. Catching poops will damage the fruits, and decrease the game score. The points gained from this mini game will be converted to game coins afterwards. The entire mini-game lasts for 30 seconds, and cost 30 game coins to play.

Figure 4.11 Mini Game – Catch Fruit Game Screen

Besides medical help, feeding, and the mini game, accessories are available to buy in the trade house. The accessories are provided for individuals who have more coins, and who would love to decorate their virtual pet so it can look pretty. Six accessories are available to the users, including the mustache, the flower, the bow, the headphones, the tiny hat, and the nightcap. Each has a different cost, but they are more expensive than general food supplies.

Figure 4.12 Trade House for Accessories Screen

Figure 4.13 The Overall FitPet Game Flow Chart

Chapter 5.

Evaluating the Effectiveness of Three Gamified Approaches: Goal-setting, Social Interaction, and the Game-based Mobile Application

The second user study was conducted to evaluate the effectiveness of gamification elements, goal-setting, social interaction including social competition, communication and collaboration, and a game-based mobile application *FitPet*. This study was conducted over a period of six weeks during which time the participants checked in with the researcher every two weeks. One control condition and two experimental conditions were designed to assess the impact of goal-setting, the social Website Community influences and *FitPet* separately. A mixed-method was adopted, with three semi-structured interviews and three quantitative questionnaires after each phase. In this chapter, participants' demographics, the study's goal and procedure, the research apparatus, and study results are introduced and presented. In the six-week field study, three qualitative semi-structured interviews and four quantitative questionnaires were scheduled for each participant. Because 23 participants were included, I had collected massive amount of data. Therefore, in this thesis, I am reporting major results and findings from the top level according to my research questions.

5.1. Study Motivation and Goal

Although a lot of studies have been conducted to understand what and how individuals can be motivated and to promote being better self, the inclusion of gamification mechanics in these studies is still a relatively new area. It has early signs of both failed and successful results, both of which showing great potential for lifestyle improvements. Therefore, *FitPet* was implemented and the study was designed to explore more design opportunities, identify design challenges, and most importantly provide design inspirations for and implications of gamification mechanics.

5.2. Study Description

A six-week long between-subject field study was conducted with 23 participants. The six-week period was divided equally into the study's three phases: pre-test observation, intervention, and post-test observation. During the intervention phase, the participants used the system and reported their experiences. This mixed-design study consisted of four quantitative questionnaires and three semi-structured interviews. Three conditions were designed to assess the engagement and effectiveness of separate gamified solutions: (1) goal-setting with *FitBit*, (2) social Website Community and Mobile Challenge condition with *FitBit* applications and (3) the *FitPet*.

Since previous pedometer studies (C. E. Tudor-Locke et al. 2002) reported a plateau in their participants' daily step count after the first 4 weeks of pedometer use, I did not design a control group who only wore a *FitBit* but had no more incentives. For the study, I expected that the novelty effect of the *FitBit* wearable device would wear off in the first 2-week pre-study phase. Therefore, increases in daily step counts observed during the *FitPet* and social group conditions were likely to reflect the additional incentives introduced by the game.

First, the physical activity data (calories burned, steps taken, activity levels) recorded by the *FitBit* wearable served as the primary indicator of each participant's behaviour change. In this study, step data was the primary measure of physical activity. Second, the interviews and questionnaires provided further ways to capture user feedback and to assess attitude changes. Third, the data from the *FitPet* sensor was used to make inferences about how participants interacted with the game and how engaged they were with the game. For example, the progression of the virtual pet's growth, levels and accomplishments in the game can reasonably be assumed to correlate to their level of engagement with the game.

5.2.1. Hypotheses

Based on my understanding of prior research discussed in Chapter 2, in this study, I assumed that all three conditions would promote participants' physical activity and encourage more steps because of the capability of self-monitoring. However, I hypothesized that the experimental group with social interaction would have a higher increase in steps than the control group because of social competitions and communications as prior studies demonstrated (Consolvo et al. 2006). Also, for the *FitPet* experimental group, I conjectured that it would be more useful for motivating steps than the control group and the social group, since *FitPet* was supposed to provide a higher level of emotional engagement for participants. I assumed that the *FitPet* and the social Website Community both would both be effective gamification approaches for promoting physical activity, compared to the control group.

5.2.2. Participants

To assess the effectiveness of *FitPet*, 23 participants (8 females and 15 males) were recruited inside and outside the SFU University, all of whom either have a full-time job (office job) or are full-time university students. Convenience sampling was used to select the participants. In the pre-test phase, background research was conducted with each individual, regarded the participants' general information (gender, age, and job types), exercise and physical activity levels, familiarity and experience with the relevant technology, and desires to change activity levels. Results are summarized in table 5.1.

Prior to their participation in this study, 5 (21.7%) of the participants used either mobile applications or health trackers to self-monitor personal data. Only 1 participant had taken part in a research study promoting physical activity, which occurred several years ago. As for goal-setting, none of the participants had a specific daily or weekly steps/activity goal. Seven of them have a general long-term goal of fitness, such as losing weight, gaining muscles, running longer and faster, or staying active and healthy in general. Out of 23 participants, 11 had experience with a *Tamagotchi* and played with it over a period of time ranging from 1 month to 2 years, all of which do not have one during the study period.

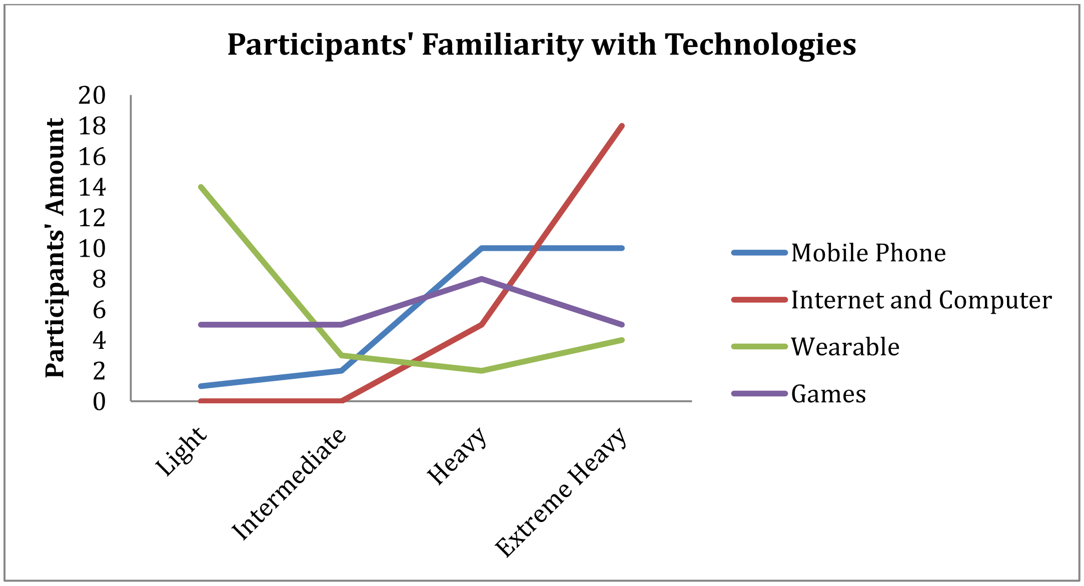


Figure 5.1 Participants' Familiarity with Technologies

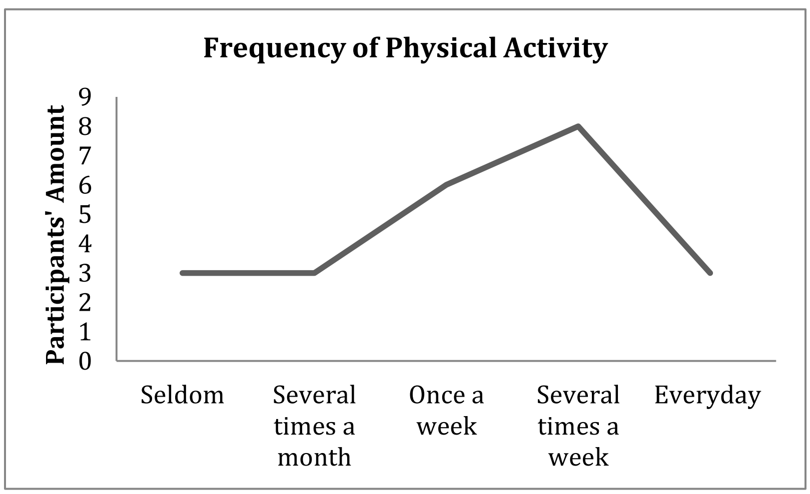


Figure 5.2 Participants' Frequency of Physical Activity

Figure 5.1 shows participants' familiarity with technology. *Light*, *intermediate*, *heavy*, and *extreme heavy* are used as the terms to describe participants' usage of technology. Originally in the questionnaire, participants were asked to rate their usage of certain technology in a 0 to 100 visual analog scale. The range 0 to 24 was classified to *light*, 25-49 as *intermediate*, 50-74 as *heavy*, and *75-100* as *extreme heavy*. From the results, all participants are either *heavy* (5) or *extreme heavy* (18) users of Internet and Computers. For Mobile Phones, it has a similar tendency as Internet and Computers, 10 people considered themselves to be heavy users and 10 to be extreme heavy users. As for Games, most participants rated themselves to be intermediate (5) or heavy (8) users. However, for wearables, most people (14) are *light* users, and they are not familiar or had prior experience with this technology. To conclude, participants are more familiar with Internet and Computer usage compared to wearables. In general, participants were mostly intermediate and heavy users of games and mobile phones.

Figure 5.2 shows the frequency of participants' physical activity. Eight of 23 participant performed physical activity several times per week, and six people did it once a week. Three participants fell into the other three categories, seldom, several times a month and every day. It can be concluded that most participants have regular physical activity routine, but a few of them in extreme active and inactive conditions.

Characteristics		**Distribution of Participants**
Gender	Male	15 (65.2%)
	Female	8 (34.8%)
Age	Range	21 – 53
	Average	30.69 (SD=8.16)
Frequency of Physical Activity	Seldom	3 (13.0%)
	Several times a month	3 (13.0%)
	Once a week	6 (26.0%)
	Several times a week	8 (35.0%)
	Everyday	3 (13.0%)

Desired Change of Physical Activity	Reduce	0 (0%)
	Maintain	1 (4.3%)
	Increase	22 (95.7%)
Frequency and Usage of Smart Mobile Phones	Light	1 (4.3%)
	Intermediate	2 (8.7%)
	Heavy	10 (43.5%)
	Extreme Heavy	10 (43.5%)
Frequency and Usage of Internet and Computer	Light	0 (0%)
	Intermediate	0 (0%)
	Heavy	5 (21.7%)
	Extreme Heavy	18 (78.3%)
Frequency and Usage of Wearable Technology	Light	14 (60.9%)
	Intermediate	3 (13%)
	Heavy	2 (8.7%)
	Extreme Heavy	4 (17.4%)
Frequency and Usage of	Light	5 (21.7%)

(General) Games	Intermediate	5 (21.7%)
	Heavy	8 (34.9%)
	Extreme Heavy	5 (21.7%)

Table 5.1 Participants' Demographics and Characteristics of Physical Activity

5.2.3. Procedure

The study lasted for six weeks. It was a field study, consisting of 3 phases, 3 qualitative semi-structured interviews and 4 quantitative self-reported questionnaires, as illustrated in Figure 5.6. Participants' names were coded into a participant ID number, and 23 new accounts were registered on the *FitBit* official website. All experiments conducted under this study earned ethics approval and participants were required to sign a consent form before participating in the study.

Pre-test Observation *(2 weeks)*: Before the pre-intervention stage, participants were asked to fill in a questionnaire about their daily lifestyle, physical activity level and routines, and familiarity with technologies and games.

During the pre-intervention phase, the participants were given a *FitBit* wearable device worn on the wrist. The participants were asked to wear the *FitBit* as much as possible. The participants were also encouraged to maintain their regular lifestyles.

A quick tutorial was given to each participant about how to use the *FitBit* wearable devices, and how to sync the data wirelessly with computer and mobile phones. They were also showed how to login to their own account and visit the *FitBit* dashboard (Figure 5.1) to access their physical activity data, from both mobile and PC. They were asked to update and sync their data through mobile phone or PC.

At the end of pre-intervention phase, steps data were collected from the users' *FitBit* accounts and the baseline levels (average steps) were established for each individuals. Then, in the interview, the participants were asked to set up individual goals for the intervention phase. Participants were instructed to start goal-setting from their baseline level, and add a little bit more (3-10%) to their baseline activity every day. However, participants were given the freedom and flexibility to adjust their goals based on personal schedules and daily routines. For example, some of them had training days and rest days, so it would not make sense if s/he set up a high level of activity on rest days.

After the pre-intervention phase, all participants were asked to fill in a questionnaire and take a 20-minute interview regarding their experience of using *FitBit* and how it impacted them in first two weeks.

Intervention *(2 weeks)*: During the experimental phase, the participants were randomly assigned to one of the three conditions. The control group has the *FitBit* data self-monitoring features and the goal-setting task. The first experimental group was also given the goal-setting task with *FitBit* data self-monitoring features, as well as social features (activity groups and Mobile Challenges). While the second experimental group could still wear *FitBit* (for capturing data), they were instructed to focus on the mobile app *FitPet* and not pay attention to *FitBit* anymore.

In this stage, all participants were encouraged to increase, maintain, or control their daily physical activity to achieve their individual goals either during their work hours or during their leisure time. They were asked to update and sync their data through mobile phone or PC every day. In addition, for the first experimental group, participants were asked to join the online study activity *FitBit* social Website Community (Figure 5.2), fulfill at least one Mobile Challenge (Figure 5.3 and Figure 5.4), add at least five other friends, and engage as much as possible with the online Website Community. For the second experimental group, the participants were asked to engage with the *FitPet* game as much as they could.

After the intervention phase, again, all participants were asked to fill in a questionnaire and take a 20-minute semi-structured interview regarding the experience of using *FitBit* or *FitPet* and how it impacts their physical behaviours in current phase.

FitBit Dashboard: Figure 5.1 shows the *FitBit* Online Dashboard. It includes movable and editable tiles, which display steps taken, calories consumed, sleep data, active minutes, distances walked and so on. Participants also had the freedom to view their friends' situations, switch periodical views of their healthy data, and manually input calories, water, and weight information.

Online Activity Group: Figure 5.2 introduces the layout of online activity Website Community. There is a leaderboard at the top that visualizes all members' step data into bar charts and rank each group member from the most to the least with the user's name and step number. Figure 5.3 shows a detailed view after opening the steps leaderboard window. Different rankings, including steps, active minutes, and distance, are available for participants to check and compare.

Challenges on Mobile Phones: Figure 5.4 and Figure 5.5 demonstrate what types of Mobile Challenges are included and how the communication and interactions could be like. *Daily Showdown* is a one-day competition, and *Weekend Warrior* takes effect only during the weekend, whereas *Weekdays Hustle* is effective for competition during the five weekdays. *Goal Day* is about how many participants can reach their daily steps goal.

For *Daily Showdown, Weekdays Hustle and Weekend Warrior* challenges, the one who has the most step data after the Mobile Challenge expired will win the competition. After a Mobile Challenge starts, participants can chat with each other, cheer-up or nudge each other. The system will send notifications to the main screen once there are major changes happening, such as "Tom just surpassed you!", "You just have 1000 steps more than Jerry!", or "You rank first currently."

Figure 5.3 *FitBit* Online Dashboard: User View

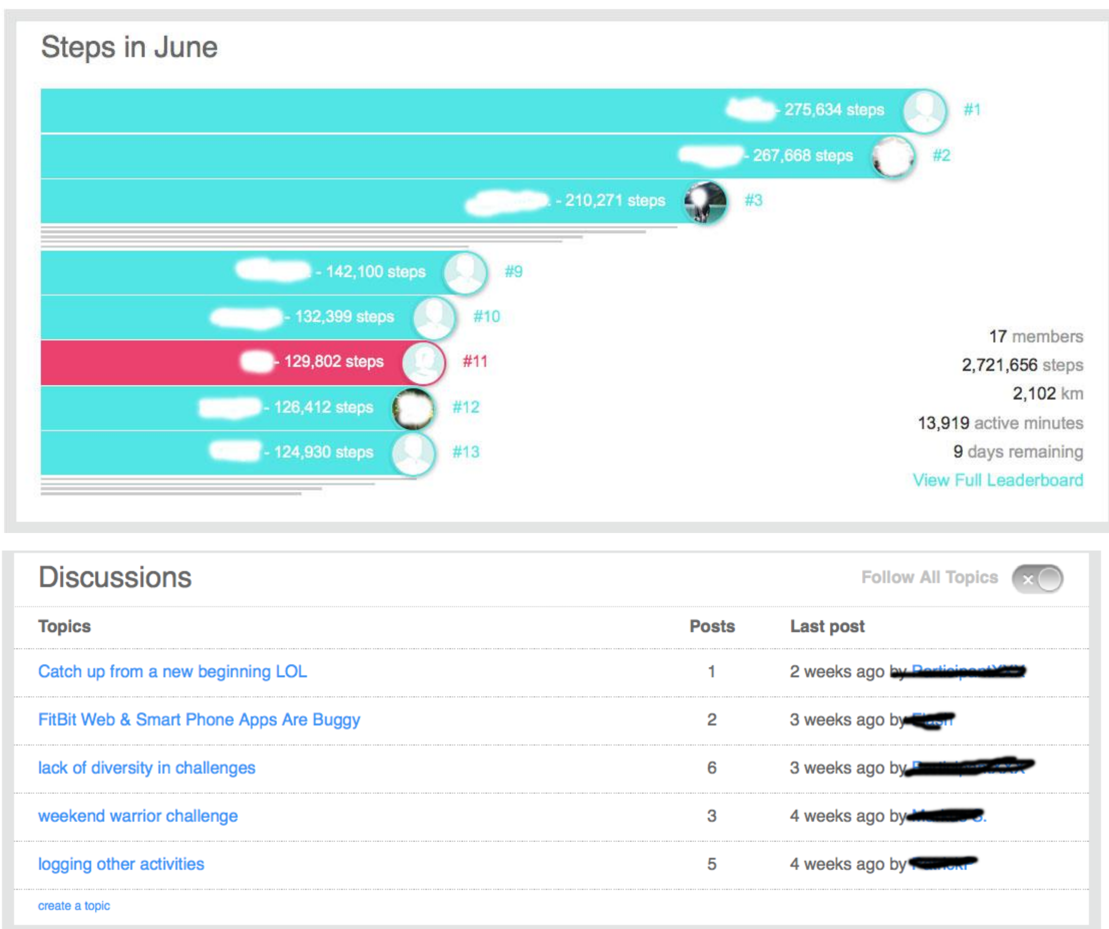


Figure 5.4 The *FitBit* Online Social Activity Community for the Study: Leaderboard, Discussion Area, and Members.

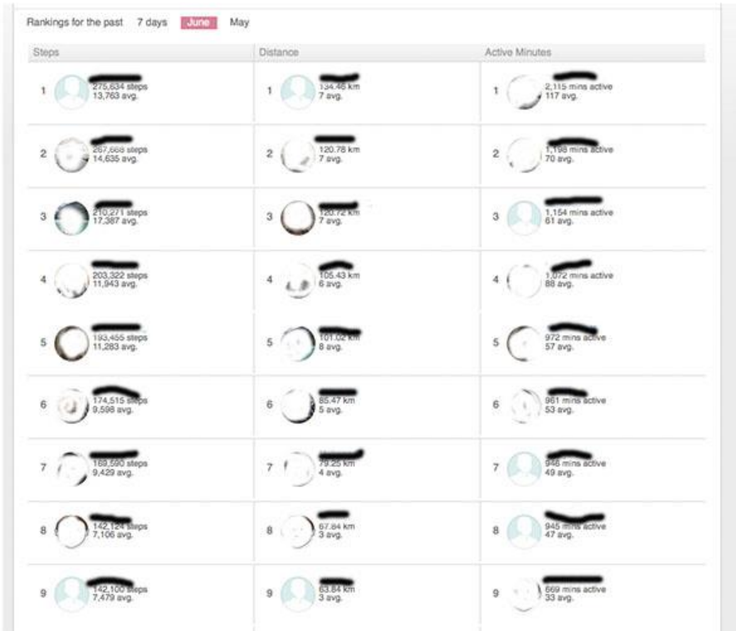


Figure 5.5 *FitBit* Online Social Activity Community for the Study: Step, Distance and Active Minutes Rankings

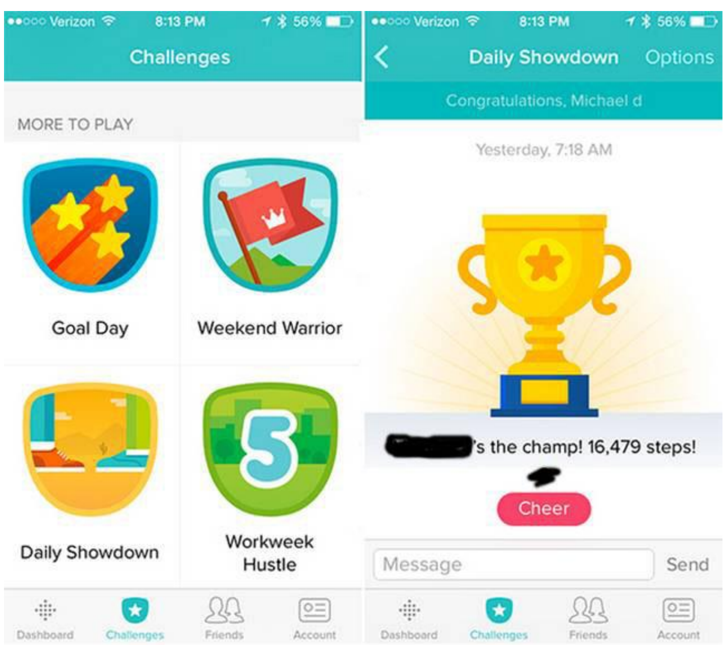


Figure 5.6 FitBit Challenges on Mobile Phones

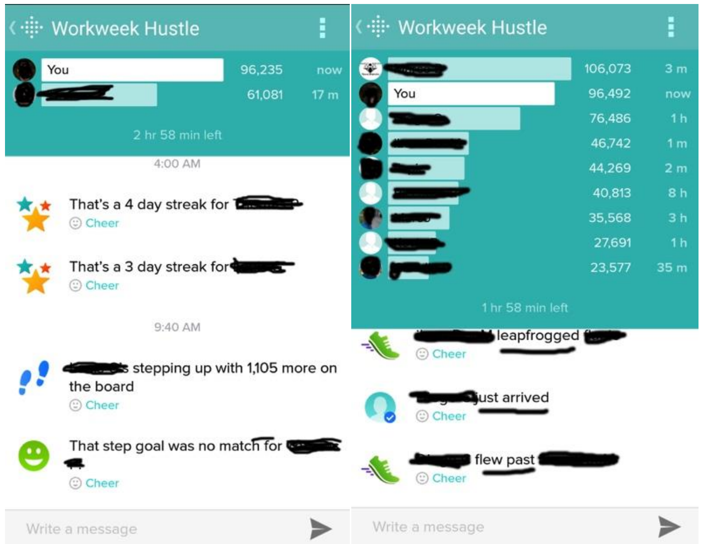


Figure 5.7 *FitBit* Mobile Challenges: User View after Accepting an Invitation and Joining the Competition

Post-test Observation *(2 weeks)*: At the end of week 4 in the study, the goal-setting, social Website Community and mobile game interventions ended for the experimental groups. But the participants were asked to adopt the most helpful methods to keep themselves motivated and stay physically active.

All participants were encouraged to keep wearing their *FitBit* for an additional 2 weeks. The final stage of participants' activity behaviours allowed me to observe any persistent effects of the gamified approaches. After the post-intervention phase, again, all participants were asked to take a 20 minutes short interview regarding the experience of using *FitBit* and how it impacted their physical behaviours. Then they were asked to fill in a self-reported questionnaire.

All of the interviews were audiotaped and then transcribed by the researchers. All of the interviews and questionnaires were coded according to categories that emerged during the study's analysis. After the interviews, open coding was adopted to analyse the qualitative results. Notes were taken during each of the semi-structured interviews, and then the key words and phrases were highlighted. Open coding was used to categorize participants' responses to the questions. For the same question, for example, annotated answers from the participants within the same study group were listed together and compared. Finally, codes were developed from the annotated answers and summarized into different categories.

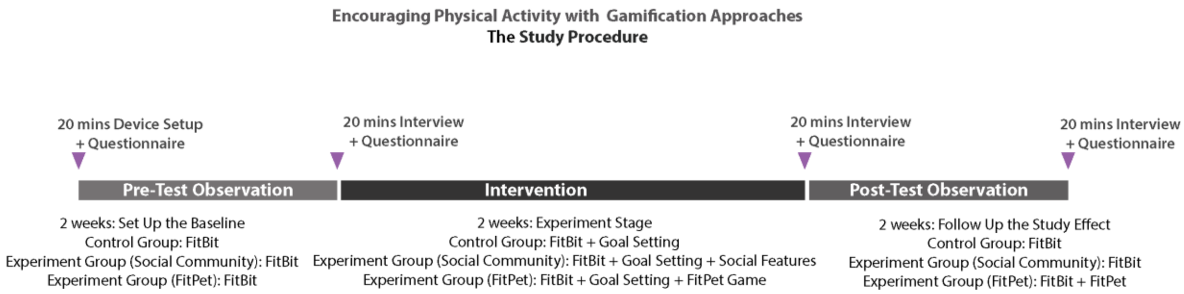


Figure 5.8 Six-week Study Procedure with Three Phases: Pre-test Observation, Intervention, and Post-test Observation.

5.2.4. Results

The results were collected from all of the 23 participants who completed the entire six-week study. To complement the quantitative findings, grounded theory analysis was used to identify recurrent patterns of attitudes towards the game through analysis of each round of interviews.

Promoted Physical Activity Changes, Motivation and Behavior Transitions

Analysis of Steps Data from all Three Groups

Table 5.2 shows the mean value (M) and standard deviation (SD) of three groups during each phase, as illustrated in Figure 5.7. Figure 5.8 indicates the increased percentage level of three groups after the intervention compared to the baseline data in pre-intervention stage. In all three groups, participants were asked to set up primary and alternative goals in the goal-setting tasks. Figure 5.9 describes the goal completeness of three groups.

The study used a between-subjects design; a participant either belonged to the control group, the social group, or the *FitPet* group. Time was a within-subjects factor, as every participant's step was measured after each study phase. Therefore, in order to evaluate the effectiveness of the three gamified conditions, a Two-way Mixed-ANOVA test was conducted to compare before-intervention and after-intervention step changes.

Independent variables were intervention conditions (goal-setting, social Website Community and *FitPet*) and time phases (pre-intervention and post-intervention). Dependent variable was the step count data collected throughout the six-week user study. To compare the effectiveness of three interventions, only steps data from before-intervention and post-intervention phases were included and analyzed.

A significant main effect of time was found, $F(2, 22) = 4.17$, $p = .02 < .05$, $r = .53$. Then to figure out where the significant differences existed, a Tuckey HSD test was run. It showed that the social group had significantly more steps than the *FitPet* group $p = .03 < .05$, and between the social group and the control group, $p = .03 < .05$. However, there was no significant difference between the *FitPet* group and the control group. Figure 5.10 showed the LSMeans of three study conditions.

The main effect of condition was non-significant, $F(2, 22) = 2.23$, $p = .12 > .05$, $r = .20$. This indicated that when the time at which step count was measured is ignored, the initial step level of participants in each group was not significantly different.

There was a significant Time * Group interaction effect, $F(2, 22) = 5.31$, $p = .02 < .05$, $r = .33$, indicating that the changes of step count in the groups were significantly different from each other. Specifically, there was a significant increase of steps in the social group. In the social group, the post-test step count was significantly higher than pre-test step data, $p = .03 < .05$. Also, in post-test analysis, significant differences were found between *FitPet* group and social group. The social group had a significant increase of steps over *FitPet* group, $p = .04 < .05$. No other differences were revealed by the tests.

These findings indicate that the social group was significantly more effective than the goal-setting control group and the *FitPet* experimental group. LS means test results are shown in Figure 5.10.

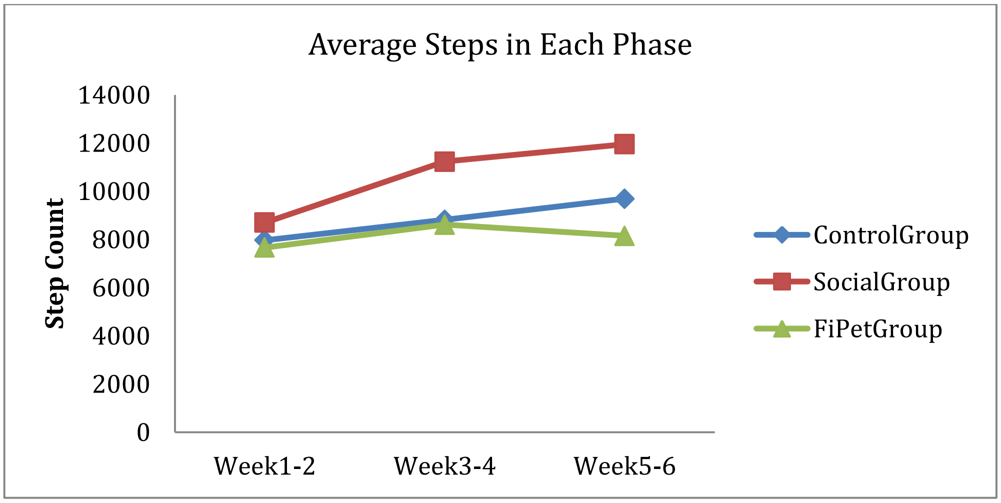


Figure 5.7 Steps Data of Three Conditions in 3 Phases

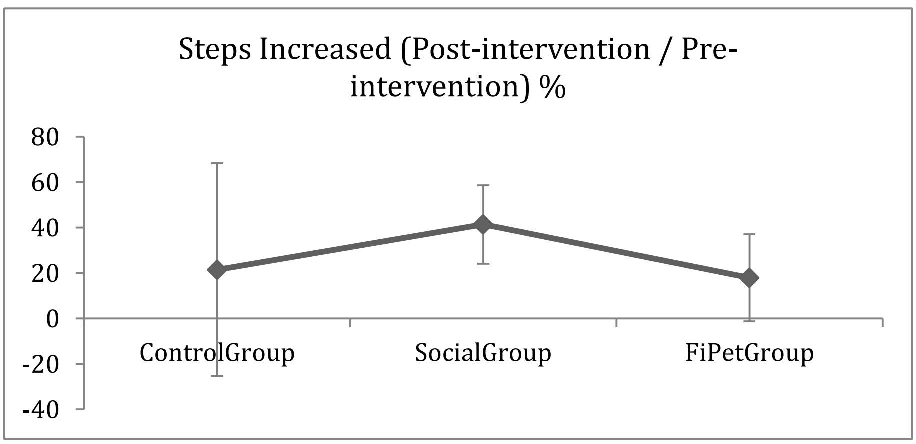


Figure 5.9 Steps Increased: Percentages of Three Conditions after Intervention Compared to Pre-intervention Phase

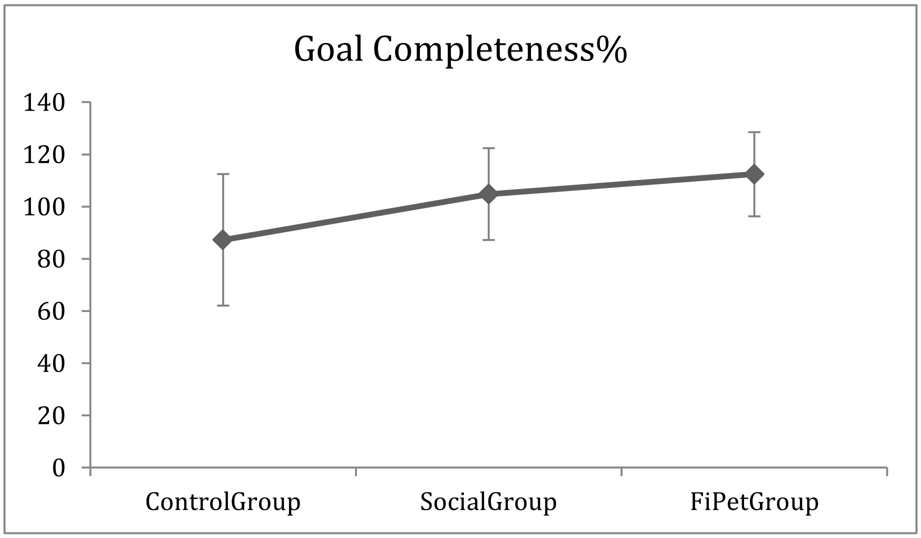


Figure 5.10 Goal Completeness: Percentages of the Three Conditions

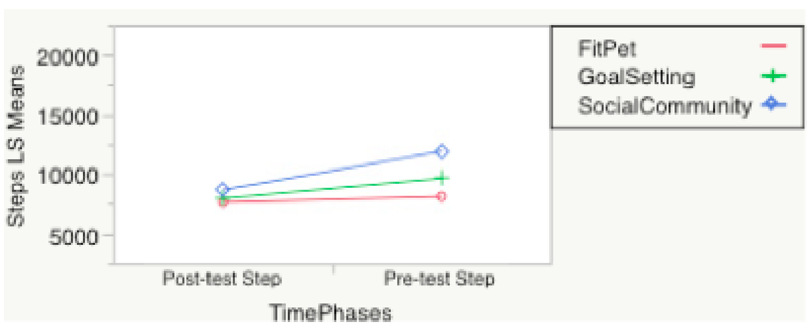


Figure 5.11 LS Means of the Three Conditions

Analysis of Self-reported Motivation and Behavior Changes

In the study, participants were interviewed and were categorized into different activity and motivation levels. Table 5.3 demonstrated all participants' changes of activity level before and after the study, with step changes and goal completeness data. Levels are defined below and are based on the TTM model (Lin et al. 2006) (Munson and Consolvo 2012):

Level 1: Ultra Casual (Pre-contemplation): a minimum amount of reported physical activity; no attention or motivation to take action regarding physical activity.

<u>Level 2: Casual (Contemplation Stage)</u>: low level of reported physical activity; intention to take action; little motivation for being active.

<u>Level 3: Transitional (Preparation Stage)</u>: certain level of reported physical activity and initial steps taken towards actions; indications of motivation to be active.

<u>Level 4: Hardcore (Action and Maintenance Stage)</u>: change in behavior occurred in the past; an active level of physical activity with a motivation.

<u>Level 5: Ultra Hardcore (Termination Stage</u><u>)</u>: an active level of physical activity; complete confidence in coping without fear of relapse; strong motivation.

Group Information and ID		Pre-test Level	Post-test Level	Step Changes	Goal Completeness During Intervention %
Control Group With *FitBit* and Goal-setting	2	4	4	1213	79.73
	9	3	4	-3539	107.51
	10	3	4	-3276	70.65
	14	1	3	4801	90.77
	20	2	3	2609	79.93
	21	3	3	9222	129.59
	22	2	3	998	52.71
Experimental Group One With *FitBit*,	1	2	3	502	77.49
	4	4	4	4735	114.48

Goal-setting and Social Interaction	5	3	4	3967	102.77
	7	4	5	4956	114.8
	8	2	3	794	93.68
	13	2	3	3080	134.47
	15	4	3	1322	90.89
	11	4	4	6658	109.71
Experimental Group Two With *FitPet*, and Goal-setting	3	1	3	-1790	110
	6	2	2	-318	99.34
	12	2	2	1189	102.58
	16	2	3	1874	124.01
	17	3	4	1255	109.72
	18	2	3	1049	146.94
	19	1	2	1824	104.35
	23	2	2	-1206	100.15

Table 5.2 Participants' Cumulative TTM Assessment Results with Steps Data and Goal Completeness, Pre-study and Post-study.

Evaluation of the Gamified Approaches: Goal-setting, Social Interaction, and FitPet Mobile App

From three semi-structured interviews, participants' experiences and evaluations using different approaches (goal-setting, social Website Community and Mobile Challenges, and game-based mobile app), are summarized at this section.

The purpose of this study was to investigate the effectiveness of particular gamification strategies and to compare the outcomes among these different approaches. Thus, in this section, I summarized the results and findings from interviews with the three groups which happened after the intervention phase and post-observation phase.

Self-monitoring and Self-reflection

All 23 participants mentioned that being able to self-monitor their activity and behaviors with the quantified systems – either the *FitBit* wearable tracker or the *FitPet* mobile game – heightened their awareness of their physical activity levels, especially their walking behavior. Particularly for the control group, which was not given other interventions or incentives besides a *FitBit* and the goal-setting task, all individuals (7 participants) reported that self-monitoring provided positive feedback. Self-reflection then resulted in higher awareness and motivation for them to make a change.

Participants (7 from the control group, 5 from the social group, and 4 from the *FitPet* group) generally found that self-monitoring acted as a reminder and the *FitBit*/*FitPet* allowed them to check on their daily progress, especially when they were not active, e.g., "*I was certainly more aware of the days when I was not walking much,*" (P21) "*It is a good motivator just to have it with you tracking your progress, even if you are not doing anything exercise-related, maybe just walking.*" (P22)

Obviously, the quantified self-monitoring would not happen without the wearable health tracker. Reflecting about certain aspects of one's life can provide valuable insights, which in turn may lead individuals to reconsider and possibly change particular attitudes or even behaviors, e.g., "*While I could not always walk as much as I wanted each* *day, it was nice to see over time how much I was walking or if I had a really active day, to see if I could walk more the next day.*" (P15)

Goal-setting

Overall, 10 participants out of 23 reported that the goal-setting task was helpful for motivating them to move and get in more steps, e.g., "*On the days when I would not reach normally 10k (steps), I would go for a walk after dinner just to reach that goal. I was surprised that the goal was so effective in getting me to go for a walk. It starts with an arbitrary goal – just the FitBit default (goal) – but I would still go for a walk at the end of the day to meet it!*" (P22)

On average, each participant set 1.8 daily step goals. Four participants in the social group belong to "hardcore" TTM type (regarding motivation and physical activity), they have "training days" and "resting days". Therefore, they have multiple goals depending on the workout schedule, e.g., "*I will work out on my pre-set schedule and also listen to my body to take rest days. I have changed my physical activity based on my long-term physical goal, not the daily steps goal asked by the study.*" (P04)

Around half of the overall participants normally started with an attainable goal, and then raised the bar if they could make it, or modified it, e.g., "*I tried to make it higher, but attainable, so 12000 steps is good for me,*" (P01) "*I do what I normally do during the day. I set a day where I can hit my goal and make one every week and steadily increase it every time I surpass it"* (P21), "*First, I add my step count every 5 days by 10% but that is too much; second, I increased step goals every 5 days by 1000 and I found I need to adjust the goal to make it more attainable.*" (P02)

Most people (13 of 23 in all three groups) set their goal such that it was not too high to reach, but still required certain effort to meet that goal in order to not feel bad, e.g., "*I go with the 10,000 steps, and I increase it if I plan to go running that day. I lower it so I met the goal everyday so as to not feel bad.*" (P07)

Three participants had no time for exercising or physical activity, owing to their responsibilities for work and taking care of their family. They mostly tried to find their maximum steps for activity, and tried to stick to the same goal without changes, e.g., "*I keep my daily goal steady. I have a pretty variable schedule so it is not super easy for me to know how much activity I will actually be able to get in a day. Keeping it steady lets me see how I did relatively each day over the week*" (P15), "*I set my step up goal to 10k steps, and check the data now and then. But I did not change it because of my busy schedule.*" (P08)

Goal-setting acted as a motivating factor for promoting activity for 10 of the participants. As P04 mentioned, "*Setting goals and achieving rewards are always good motivators, whether in life or physical activity*", e.g., "*Goal-setting provides motivation for me, and it acts as a reminder for me to check in more often. Setting a goal did make me more engaged with it.*" (P09) Goal-setting tasks encouraged self-reflection too, e.g. "*I set up my goal at the end of the night as to how active I will be the next day*" (P09), "*I did not change my goal from the initial 10k step; it did help me reflect on a daily basis though.*" (P22)

However, for three individuals, neither step count nor step goals made a great deal of sense for them. Although the health tracker could make participants more "*aware of stride length and how many steps per km*" as P02 said, she also mentioned, "*Healthy and fit are what made my body and mind feels better. I do not really care if step count is a certain number.*" (P02) Another participant also illustrated the difficulty of goal-setting, "*Goal-setting can be effective as long as you can stay motivated by yourself, which is hard to keep after certain period of time.*" (P01)

Social Website Community, Mobile Challenges, and Interactions.

Seven out of eight individuals from the social group reported they enjoyed having social interaction with others, but it only limited to the Mobile Challenge activities not the online activity community. All 7 mentioned that such a type of social Website Communication and interactions happening in Mobile Challenges had major influences over their motivation for performing physical activity. Furthermore, the social aspect of Website Community groups and Mobile Challenges helped participants keep their personal goals in check.

Overall, all participants enjoyed and liked the Social Mobile Challenge feature, e.g., "*It was surprisingly engaging. I did not think that I would be so engaged with the app and* *my friends on FitBit"*, "*Having a Challenge and a few nudges through the app helped to be more engaged with the Challenge.*" (P05)

Compared to the online Website Community, the Mobile Challenge component was thought to be more fun, enjoyable, and effective in motivating physical activity by all 8 participants. P05 said, "*Challenges are more effective because of their limited timeframes and reminders of what everyone is doing*", and P08 also mentioned, "*Not so much the activity group, but the Challenges since the app sends constant reminders of what is happening.*" As for the responses and experience about the activity community component, one participant observed, "*The people in the activity group do not talk enough so engagement goes down.*" (P07)

Competition with each other did influence the participants a lot, but they also enjoyed other type of interactions as reported by 7 participants in the social group, e.g. "*Loved the Challenges, fun and competitive, opened the door for socializing with others*" (P01), "*Really liked the Challenge feature. Fun, motivating, and funny conversation feeds between the members involved. Also got my friends and family involved like 'oh, how are you doing in the rankings now?'* " (P15)

Members' background (physical activity routine) and the group size mattered to group members' social engagement and the motivation for staying physically active according to all 8 participants from the social group. For instance, one of the "hardcore" level participants, P04 reported, "*I did use the Challenge feature. It did not promote more activities but I think that helped others in the group to be more active. I think the study group needs to be bigger to have Challenges to work effectively. Or has more people who have the same activity background as I do*", and P05 said, "*It would be better if the group (was) doing the same type of activities. So it (the Challenge) is harder. Right now, I could easily beat other people.*" As for the size, P08 mentioned, "*The activity group is really competitive therefore motivated, and I like it. Group size is good, around 8-15, I would not like a larger group of more than 20 people.*" P13 said, "*I would prefer to with a 30-year-old group, who has the same healthy condition with me. It is motivating to keep track of the rankings in the leaderboard.*"

Engagement with wearing the *FitBit* and self-monitoring faded as time went by as reported by around 1/3 of the participants. However, social features prompted participants to check their physical activity more often. Mobile Challenges brought more dynamic communication, working towards a goal, and user engagement to the participants. But the types of Mobile Challenges are also reported crucial to the effectiveness of such social gamification mechanics, e.g., "*Although I liked it and it motivated me, the Challenges were too simple for me after the two intervention weeks. They are all about having the most steps within certain timeframe, which is boring. I would prefer to try new ones*" (P07), e.g., "*the Challenges are boring – they all just focus on getting the most steps rather than more interesting aspects like ways to improve steps counts at various points.*" (P08) Again, participant reported, "*this approach can be effective as long as (I) stay in touch with the Challenge group.*" (P05)

Table 5.4 shows the engagement situation of each participant in the study activity group, as well as the Mobile Challenges they participated in. Although most participants neither posted in the activity community nor discussed with others (about their questions, physical activity conditions, and so on), they joined lots of Mobile Challenges and tried most of the social interaction features.

ID	Friends Added in *FitBit* Network	Activity Community		Challenges	
		Public Posts in Activity Community	Frequency Check Group Leaderboard	Challenges Participated	Interactions with Other Participants
1	5	1	1-2 times/week	2 Weekend Warriors; 1 Weekdays Hustle	Cheer-up, Nudge
4	7	3	3-4 times/week	2 Weekend Warriors; 1 Weekdays	Cheer-up, Nudge, communicate

				Hustle	(conversation)
5	10	5	Once	2 Weekend Warriors; 2 Weekdays Hustle	Cheer-up, Nudge, communicate (conversation)
7	8	7	1-2 times/week	2 Weekend Warriors; 1 Weekdays Hustle	Cheer-up, Nudge, communicate (conversation)
8	7	0	Once	1 Weekend Warriors; 1 Weekdays Hustle; 1 Daily Showdown	Cheer-up, Nudge, communicate (conversation)
13	8	0	3-4 times/week	1 Weekend Warriors;	Cheer-up
15	9	0	1-2 times/week	2 Weekend Warriors; 1 Weekdays Hustle	Cheer-up, Nudge, communicate (conversation)
11	5	0	Once	1 Weekend Warriors; 1 Weekdays Hustle	Cheer-up, Nudge, communicate (conversation)

Table 5.3 Experimental Group Two: Social Community and Interaction Information during the Intervention Stage

Game-based Approach: *FitPet*

As for *FitPet*, all of the 8 participants appreciated the idea of converting their healthy data to something game related. However, they stated their problems and concerns using such a mobile application. Suggestions were given regarding design ideas and game mechanics. Four out of all participants continued using *FitPet* in the post-intervention period.

All 8 participants liked the idea of associating their health (steps) to the health of a virtual pet, which was to realize something "bigger" and not limited to oneself. But they still felt there were things missing to make them more engaged, e.g., "*Yes, I do care about it, because I do want the pet to be healthy. But it might also because I know that someone is monitoring*", "*I felt bad when I did not meet my FitPet goal, I became very aware that I was not walking enough*" (P17), "*It is a unique gameplay element that gets used very little in games*" (P23), "*There is a mixed-feeling. I like the game and idea, but I do not feel motivated enough. The game can be more challenging.*" (P18)

Participants felt certain degree of emotional investment and engagement with the pet; however, they felt it was not strong and powerful enough. For example, "*I am happy to see the achievements that I did to my pet*" (P03), "*Yes, it makes me feel emotionally invested in it, but not strong enough for promoting motivation*" (P16), e.g., "*when the pet is sick, I want to ask 'why', 'you are so well loved, you must be broke', and when it is healthy, I felt, 'good, you should be'*, and "*I really want to touch the pet, to build connections with him.*" (P06)

Five participants suggested that the application should be made to run whenever they were physically active, instead of manually opening the software. Four of them said that connecting with other wearable health trackers' API would also work for them to play the game, e.g., "*I did not use (FitPet) very much after the intervention phase because the app could not run in the background, so I need(ed) to remind myself (to) open it every time before recording steps*" (P12), e.g., "*it would be more effective if (it is) running in the background"* (P03), e.g., "*It would be nice if it can run in the background or connected with FitBit to grab the data, and have some notifications.*" (P03)

Four participants mentioned that they would prefer to have more interactions and more virtual rewards with the virtual pet besides current gameplay. One participant who was at "hardcore" level said "*I feed it every day to keep it happy. (This) Does not help me promote steps because there is not enough reward in the game. (The game) Needs more (interactions) or different goals to promote my activities*". Another participant, who was a gamer, reported "*For the first couple of days, yes! After that, I had done everything I could, many times and lost interest"* (P23), e.g., "*I would prefer more interactions in the game, say more accessories, more selections of food, and things being more expensive for me*" (P03), and "*There could be more interactions, mechanics and connections in the game, like Animal Crossing, Farm Feed. You could collect items and even collaborate with other people.*" (P06)

Also, four participants gave the feedback that to be more motivated and have more awareness of how the pet was doing, prompt notifications would be significantly helpful. As suggested by P12, "*Notification will remind me to think about it*", and by P17, "*I wanted to use it more, but I sometimes forgot until the end of the day*", "*I would feel emotionally engaged with it only when I turn it on. Then there is an emotional connection for me*" (P03), and "*Use notification to pop it out (of) my head, or vibrations as a reminder.*" (P18) However, one participant said the game idea would not work out well for him because he was not that type of person who was into things like this.

The mini game feature incorporated in *FitPet* was perceived as a fun and interesting game mechanic incorporated in *FitPet* by 6 participants from the game group. However, it needed more narrative elements to catch up with the overall concept. Besides this, participants liked to have mini games and preferred to have more, e.g., "*More mini games would be great*" (P06), and "*The mini game was fun. But I felt disconnected with the gameplay. Should be more narrative element or story there*" (P18), and "*It would be nice if I can also compete my pet with my family members or friends, and even fight against their virtual pet.*" (P16)

For 3 participants who were Android users, battery life was the biggest issue, e.g. "*The mini catch game is fun, (and) I really like it. That is an interesting idea but my battery does not support it*" (P19), and "*My phone heated up after 15 minutes each time I open the application.*" (P23)

Behavioral and Motivational Changes

Behavioral and motivational changes were affected by interventions during the study. For “hardcore” level individuals, it was hard to change behaviors or motivate more activity since they were already pretty active and stuck to a relatively professional workout schedule. However, for participants who were at “ultra casual”, “casual”, or “transitional” levels before the intervention, the incentives did encourage more activity. Self-monitoring and self-reflection were motivated by *FitBit*, goal-setting task, social factors and *FitPet*.

Participants in the Goal-setting control group reported the changes they observed, e.g., “*I would take stairs not the escalator/elevator, and walk long way around a lake after lunch time near my office*” (P20), “ *(I feel) more active, lots of energy, understand the metrics behind exercise improved quality of self-reflection*” (P10), and “*It is funny that I lost 4 pounds. It is a matter of being … for me.*” (P01)

People from social group said, e.g., “*Now I have longer walks with my dog in the evening, and I even use it on my stationary bikes to count more steps-inside my shoe*” (P01), “*I run more times in a week, and my activity level is fairly high. I am more motivated to get out and run. I also changed my wake up time to 5 am to accommodate additional physical activity. I think it is positive, but I am not sure if I am overdoing it*” (P07), “*Though I was really active*, *I actually gained a few pounds! I guess it might be muscle weight since I am doing so many activities. But I still need to check and figure out*” (P07), “*I have become very aware of how much time is spent sitting in front of a computer*. *I have really noticed that I need to be very conscientious of the time I have. I am too busy and need to force the time to exercise.*” (P11)

Individuals who were in *FitPet* group mentioned, “*Last summer, I never went out home because I was too fat. But now I am more confident. Now I have more active time, (and) I walk and run more. I feel good. But I still feel there is a need to increase my activity*” (P22), “*More activities make me more aware of both my psychological and mental health. I feel happy because I engaged with more physical activity.*” (P17)

To sum up the findings from the study interviews, for the goal-setting approach, participants already had known their baseline level after the pre-test study period, but most people still did not know how they could or should set an appropriate personal goal according to their context. From the interview, some people set an “arbitrary” goal. Thus, proper guidance and professional advices are important for an individual to understand how to set goals as the goals can vary considerably.

For the two types of social interventions tested in the social group, Website Community and Mobile Challenges, I concluded from the interviews that the Website Community is a more passive way of communicating and is not as engaging, whereas Mobile Challenge was active, and offered more synchronous communication and collaboration, which participants found to be fun and engaging. Participants cared their rankings of physical activity in the Mobile Challenge leaderboard but not in the Website Community, for instance. More importantly, besides the generally used “peer competition” strategy, “peer-cheer” communication was also considered and reported to be a critical encouraging factor for the participants to feel engaged and connected. Furthermore, as summarized from the interviews, what mattered to participants’ experience of social interaction were the size of the group, the background and context of its group members, and the frequency of the Mobile Challenge.

The *FitPet* mobile game did not perform as well as was expected. Participants generally liked the main design idea. However, they mentioned the game did not provide enough awareness or feedback, and it did not need much investment. The gameplay was not difficult for them, especially after a few days of adaptation. For these reasons, a narrative element or story about the mini game would improve its viability. Even for a small-scale game like *FitPet*, the difficulty of challenges in the game should be controlled in order to match players’ skills. In a game like this, player experience and game flow are important because it is how people can become more involved in it, investing more effort and emotional engagement.

Chapter 6.

Discussion: How to Promote Physical Activity Through the Lens of Gamification

Gamification, the use of game design elements in non-game contexts, is often implemented in persuasive systems aimed to promote motivation and encourage physical activity. The six-week field study explored different gamified approaches and examined the effectiveness of goal-setting, social Website Community and Mobile Challenges, and a game-based mobile application. The results and findings highlighted design challenges, design opportunities and design implications for further implementation and future research investigation.

From the interviews, I have discovered that the most important reason for participants who have gone through (physical activity) behaviour changes after the intervention is that they felt feel better and achieved things. So they wanted to continue feeling good as mentioned by P01, P11, P22, and P17 in Chapter 5 (under the Behaviour and Motivation Change section). It is not about enjoying the technology or winning social competitions. Participants who have gone through positive changes reported they had more energy, were satisfied with active and positive body conditions, and even lost some weight. From interviews with the participants, as illustrated in Chapter 5 (under the Self-monitoring and Self-reflection section), the study interventions worked as gamified incentives for promoting self-awareness and self-reflection. The more emotionally engaging the participants with the gamified techniques (goal-setting, social interaction, or *FitPet*), the more self-awareness and self-reflection were gained about one’s physical activity.

Therefore, in this chapter, I summarize the research work of this thesis and compared it with prior research. Then, I proposed design challenges and opportunities for encouraging and promoting physical activity. In this thesis, I mainly focused on two promising strategies (social Challenges and the game-based approach) and two crucial factors influencing users' motivation (personal awareness and emotional engagement). I conclude with current design advantages and weaknesses of the tools used in the interventions, for which my implementations of *FitPet* were less compelling than anticipated. Finally, study limitations are listed for reflection and for further development of future research prototypes or study design.

6.1. Reflections and Implications for Intervention Design

Quantified systems display data in a concrete numerical form, facilitating reflection on one's level of physical activity. Gamified systems add game-like elements on top of the numeric data. Presumably, gamification turns physical activity into a more enjoyable and interesting experience, thus motivating users to engage more in physical activity. However, this assumption has yet to be empirically established and been challenged by several researchers (Nicholson 2012) (Deterding 2015). In this section, reflections from the user studies and interviews are discussed. Design challenges and opportunities, as well as implications are summarized based on gamification mechanics.

6.1.1. Goal-setting: More than Providing a Baseline or Pre-set Goals

Goal-setting was not a successful strategy as perceived by participants in this study compared to prior studies (Consolvo et al. 2009). Around half of the participants had trouble meeting their primary goals or secondary goals during the intervention period, and 18 of them stopped setting the goal in the post-observation period. A number of complex issues seem to have affected these outcomes.

For half of the participants, goal-setting did work out well. But as is known from the interviews, everyone might have a busy schedule or family responsibilities, which are in a higher priority than completing a step goal. Moreover, once the participants could not meet their goals in such a circumstance, they are less inclined to repeat it; some would even start to hate such a strategy because they reported feeling bad when they did not meet their goals (such as mentioned by P01 and P02).

Regardless of the success or failure participants experienced regarding their major goals, participants also made alternative or multiple goals during the study. These alternative goals were adopted when the participants had problems fulfilling their major goals because of personal reasons. (These alternative goals seemed to have functioned as an adaption that allowed participants to sustain their motivation, despite unanticipated complexities.) Alternative goals were thought to be within participants' capabilities and they anticipated completing the goals more easily. When participants failed in meeting their goals in a few days in a row – no matter if they were main or alternate goals – they would feel upset and do not care about it anymore. Therefore, it is not a matter of reminders or checking in (self-monitoring); rather, it became an emotional frustration as mentioned by P01 and P02 in Chapter 5 (under the goal-setting section). Thus, goal-setting was less useful and helpful for promoting awareness towards physical activity level as suggested in prior studies (Consolvo et al. 2008) (Munson and Consolvo 2012) suggest.

As one of the participants stated in the interview, goal-setting was only effective for promoting awareness and activity ***when*** he had the motivation to keep it. For 4 participants who were at the "hardcore" activity level in the social and control groups, goal-setting did not really help them. They already have a pre-set workout schedule or training days, and rest days, and may only care about completing their specific work out regardless of the step count. In a sense, they are consistently meeting and maintaining a goal that they previously made. In this context, participants are the TTM-defined "termination level", and are maintaining but not pursuing behavioural change.

A significant amount of interesting feedback inspired me to further improve the goal-setting task. Foremost among these related to providing ways to take individual contexts into account when considering goal-setting tasks. For example, proper guidance and advices from professionals about how to set up personal goals – instead of a single step count number or active minutes – might be more persuasive and more motivating. Even a recommended (minimum or maximum) goal for users, based on their age, body index (weight/height), and historical activity/exercise level, may be more useful than normative baseline data or the mission to "just promoting more steps" regardless of what that means to individual participants.

6.1.2. Social Interaction: Online Activity Community – Passive Communication and Engagement

Interviews with participants revealed that they had limited communications with each other through the online activity Website Community. Moreover, the participants perceived the social interaction within the Website Community as an ineffective approach for motivating activity.

Staying in touch with the social group was assumed to build social engagement among group members. However, there was not a lot of evidences that this occurred in expected ways such as discussion, texting or cheering-up across the Website Community website page.

A few participants reported that they also joined other activity groups, such as Vancouver Mom Group, Hockey Group, and so on. But no social invitations or active discussions happened in these other groups either. The participants who joined other groups were mostly ranked around the middle of the Website Community leaderboard, so it is safe to assume that they did not really care about it or check it frequently. For them, the online Website Community was not engaging.

A number of factors may account for this relative lack of social engagement in the online Website Community. First, the researcher (me) organized this community and participants were passively invited to join. Therefore, they joined as part of a research study, had anticipations, and then checked in the leaderboard within the online group a few times. Second, when a participant checked in, there were few things to do. Third, the engagement or lack of it among other members of the online social Website Community mattered. For instance, a few participants reported that they felt depressed because of a lack of timely notifications and feedback from others. These were the three major reasons that lead to the unsuccessful gamification design of the online Website Community.

From the interviews with participants, the following suggestions were made to improve the engagement with social interaction.

Social Interaction: Peer-cheer vs. peer-competition:

From the qualitative interviews of the social group, 7 out of 8 reported they enjoyed the social interaction with others, especially the Mobile Challenge events. As summarized from the conversations with P05, P08 and P07, social competition was one of the main factors that drove participants to be more competitive and physically active because of the peer-pressure. But as they (P01, P15) pointed out, the fact that group members within a Mobile Challenge can cheer up or nudge each other encouraged them equally in peer-competition. This is because the emotional connectivity afforded by the Mobile Challenge engaged them more with other group members, and with the Challenge itself. For those reasons, I named such social interaction “peer-cheer”.

What type of groups to join:

All of the participants mentioned that they preferred to join a Website Community with their friends or co-workers rather than strangers. Furthermore, four of the participants also suggest having groups which have members who are in the same level of physical activity or exercise routine. One said that she preferred to be in the same age group, while the others mentioned that she had a baby to take care of so she would join an active “mom” group.

It is important for people to be aware of or at least get a sense of whom they are communicating and competing with. People work or live in the same environment have more compatibility than strangers, and less excuse for being physically inactive. But if the other members share similar physical activity or are at the same level of physical activity, participants think that is helpful for motivating more steps.

What the group size should be:

The size of the group does matter to the effectiveness of the gamification strategy and the degree of engaging with it. All participants explained that a smaller group would be more engaging and interesting for them to participate. Smaller size can make people feel more connected with others, leading to more possibilities for social interaction. Six out of eight participants said the “small” size could be around 8 to 15 people (like in the study condition), and the best number is 10 for them. The other two suggested somewhere around 20 would be a good fit.

6.1.3. Social Interaction: Group Mobile Challenges – Active Engagement

Different from the results of the social Website Community, social Mobile Challenges were generally considered to be fun and engaging by all participants. In a Mobile Challenge, participants had the option to start a Mobile Challenge, and each individual had the right to accept a Mobile Challenge or reject it. Besides social competition, which was usually implemented as a gamification mechanic (Lin et al. 2006) (Zuckerman and Gal-Oz 2014), being fun and able to get support from each other were crucial reasons for participants stay engaged and keep checked in .

Interestingly, in the social group, a participant felt better if s/he could achieve a high rank in the Mobile Challenge leaderboard. Both the Website Community and Mobile Challenge had a leaderboard showing the rankings of all members’ physical activity data. Participants felt enthusiasm and engaged with the Mobile Challenge leaderboard. Unlike the leaderboard of the Mobile Challenge, participants felt indifferent about the Website Community’s leaderboard. In the Mobile Challenge, however, members could know each other better and get more involved with the social event because of the synchronous communication afforded by the Mobile Challenge’s live chat window. Thus, these members reported experiencing more close relationships with each other. In the Mobile Challenge group, some are co-workers and a few of them are even friends. Therefore, according to the feedback from participants, I propose the following design implications.

Besides social competition, implementing social collaboration in an engaging way:

The Mobile Challenge really brings people together. The participants can communicate with each other, even "make fun of each other" (as said by P08), cheer up and nudge each other, and experience interesting conversations. Besides social competition, participants can even have social networking chances through the real-time chat window. Social interaction is enriched in the Mobile Challenge context in terms of what one can do with others. Participants thought the ranking and leaderboard in Mobile Challenge motivating and conversations in the chat window hilarious. Participants would be willing to check back more frequently to make sure not to be the last one in the Mobile Challenge's leaderboard.

Designing a variety of challenges:

All participants tried at least two types of Mobile Challenges during the intervention weeks. Half of them continued trying Mobile Challenges with others in the follow-up period. However, three participants mentioned they liked the Mobile Challenges but all of them were too simple after a point, which are all about having the most steps during certain timeframes or intervals. Therefore, they felt a little bored after a few times. More type of Mobile Challenges would be more helpful in promoting activity. For example, as the participants suggest, implement flexible and interesting Mobile Challenges, such as being active (or have certain steps) during every hour on workdays to avoid sitting to long in front of the computers.

Have co-workers and families involved in a small group size:

For the social aspects, participants felt positive about interacting with each other. But the negative aspect was that participants worried that if there were all strangers in the Mobile Challenge, other members within the same social group might not be less willing to communicate as frequently, and might not be as reliable; therefore, the Mobile Challenge might thereby become more of a dull time instead of a fun time.

When involved in the Mobile Challenge together with co-workers or friends, participants can find peer-pressure from the group. It is also interesting for the participants to see where they rank among the population that shares a similar work routine. The Mobile Challenge leaderboard shows how the participant is doing in relation to other people dynamically. So the participants could be motivated to be more active. Being able to work out and Mobile Challenge together with family members would also be enjoyable and fun. One participant said he wished there was a way to keep his kids involved. He explained that his kids also needed more physical activity and they were really interested in what he was wearing and doing. Moreover, his wife also asked him "why don't you sign up the study for me?"

Similar to activity groups, most participants reported that they felt people would stay more active in a smaller size of social group. They preferred to have 5 to 8 people in each Mobile Challenge. Thus, if the activity Website Community size was around 10, they could switch to different Mobile Challenges and have alternate members in each Mobile Challenge.

Frequency of the Mobile Challenges:

After a few times of trying out Mobile Challenges, there were cases where participants' invitations were rejected or ignored by others. From what I learned during the interview, people felt too physically tried to keep themselves in a constant active state as suggested by P05. A few participants told me they did a *Weekend Warrior Challenge* for two days, and they did a *Weekdays Hustle Challenge* next which lasted for five days. Therefore, they were too exhausted to accept any new ones after all seven continually active days. From this case, a conclusion can be drawn that because of more communication and social dynamics, Mobile Challenges are fun and engaging. Such mechanics should be deployed to plan the frequency of participating in Mobile Challenges so that people would not feel tired or exhausted to get involved in such interventions.

Make historical records and information of Mobile Challenges available:

In the *FitBit* Mobile App, all of the activity data, including the leaderboard rankings, conversations, and virtual trophies, disappear a few days after the Mobile Challenge has been completed. From the interviews, participants felt disappointed that the Mobile Challenges did not exist anymore, and that everything was eventually gone.

Historical data would be able to support more self-reflection and self-comparison of the participants across various Mobile Challenges.

Incorporating tools or methods for physical meet-ups:

Besides online social interaction, three of the participants suggested implementing physical social meet-ups to current design. They argued that when the individual needs to show up, people would feel more obligated. When asked about motivation for being active in the post-intervention interview, one participant answered that participating in a group activity and meeting with his friends were his current motivations for going to the gym 3-4 times a week. Another participant said she was encouraged by her colleagues and registered for a gym membership, so that they could work out together. Therefore, in future research, providing meet-up accesses in persuasive technologies could be studied and its effectiveness could be tested.

6.1.4. Virtual Pet-keeping Game: it is all about Awareness and Emotional Engagement

On average, the virtual pet-keeping game was not perceived as an effective approach for promoting steps or building emotional connections between the game and performing physical activity. Although all participants said they appreciated such game ideas, they felt a lack of feedback and inadequate awareness when they played the game.

Provide enough awareness and feedback of health data in health related games:

In the interviews, participants said that they liked the idea and current mechanics about how things worked, but wished they could be more aware of the virtual pet's health condition and growth level, through the mobile phone's reminder or notification system. Currently, they reported that they needed to remember to run the app every day during the intervention, which became annoying. Participants suggested that to be more engaging, *FitPet* should send out regular notifications about how the pet is generally doing and what the pet needs the players to do.

Proper rewards system and challenging gameplay allows players want to engage more:

Rather than easy-surviving mode, six out of eight participants prefer more difficult and challenging gameplay. Four also mentioned that more suitable virtual rewards for doing well were necessary for continuous engagement.

The virtual pet was designed to have a really sick appearance and never die in the gameplay. Such rule was deployed to prohibit the game bringing too much frustration or negative feelings, as what happened in *Fish'n'Step* (Lin et al. 2006). However, half of the participants mentioned that they would prefer the pet to be dead if not well attended by them, so they could have more pressure and obligation to check it more frequently.

Therefore, in the future research and prototype design, participants suggest implementing more difficult gameplay, so that the rewards are worth it and the game is more engaging. Besides the major game mechanics, a few participants said more options of the virtual pet would be nice and more facial expressions which represent differently the pet's health level would be more motivating. Game mechanics like unlocking pet level, unlocking pets' types and items/accessories, and mini games were suggested. The unlock-level mechanic would increase the overall difficulty of the gameplay, for which the participants might be promoted to have more steps towards the goal.

Participants did care a lot about the visual design of pet's appearances, sick or healthy, small or large. Despite the growth of the pet's level, three out of eight participants told the researcher that they liked the pets in level 1 and level 2 rather than level 3 or 4. They thought pet in level 1 was tiny and adorable, whereas level 3 looks boring and old.

Most participants mentioned the mini catch game multiple times during the interview. They considered it to be fun and interesting. One said the mini game was actually part of his motivation for getting steps besides keeping the pet healthy. Other participants recommended having 2 or 3 more types of mini games that could be interacted with. From this perspective, besides virtual pet-keeping game mechanics, perhaps other classic and mainstream games (like Angry Bird, Temple Run, and so on) can also shed light on how to design game-based approaches for promoting health behaviours.

More than keeping a virtual pet – be part of something bigger than oneself:

As discussed in the book *Reality is Broken* (McGonigal 2011), one of the motivations gamers have for playing games is that they want to be part of something bigger than oneself. This facet of motivation was also brought out by two of the participants. One suggested implementing a game with narrative elements, where the players can run to collect items, find shelters, and save other people to survive the attack of zombies. The other said he would prefer a virtual pet social community, where his pet could visit other people's pets. So they could collaborate and explore the game together with each other, fight against other pets, or doing something interesting. From their feedback, a great potential of how game mechanics can be incorporated into persuasive technologies was highlighted.

6.2. Study Limitations

This was a study to learn about participants' experiences with various gamification approaches and strategies in an effort to inform the design of applications to support physical activity. As such, it has a few limitations as listed below:

Weather at the Great Vancouver Area influences physical activity to some degree. As mentioned by the participant, weather was one of the reasons for maintaining activity level and staying physically active for her. In the winter, her activity would go down. This can also be part of the reason for other participants too, which have a high level of activity across all three groups in the study.

No FitPet social community condition available for comparisons. No social features were implemented into the *FitPet* game so far. Therefore, it cannot be known whether the game with social components will be more effective than current version, or the social Mobile Challenges on *FitBit*. Deploying social elements as one of the game mechanics should be considered in future research and prototypes.

FitPet users' activity was not as fully tracked as the FitBit group. Since it is located on the mobile devices instead of a wearable wristband, some users tend to forget it sometimes. Although the accelerometer in the mobile phone tends to count more steps compared with *FitBit*, people wear the *FitBit* more frequently than interacting with *FitPet*. Besides, a few *FitPet* users encountered battery issues. On average, three Android users could not use it longer than 20 minutes. So *FitPet* steps were not tracked as completed as *FitBit*, which would impact evaluating the effectiveness of *FitPet* gamified approaches.

Both FitBit and FitPet could not identify other types of physical activity besides walking and running (like yoga, climbing, stationary biking and so on). Although *FitBit* allows user to manually input exercise that cannot be tracked or when users forgot to wear the device, missed steps data could not be logged. Therefore, there were some missing steps when participants forget to wear *FitBit* or open the *FitPet* application during the study period.

Potential novelty effect of the technologies. Although half of the participants have used wearable and persuasive technologies before, none of them tried the Mobile Challenge activity or the *FitPet* game. Thus, during the two-week intervention phase and the two-week post-intervention phase, those gamified strategies might still have novelty effect over certain participants, leading to possible inaccurate results when evaluating the effectiveness.

To address these concerns, future studies should consider allowing synced data between wearable health trackers and the mobile games. The factor of weather should also be taken into consideration, as it may affect a participant's physical activity opportunities to maintain or increase physical activity. A longer field study, such as one lasting more than three months or a year will be more helpful for understanding the sustainability of the gamification mechanics developed in this study's intervention.

6.3. Critiques about Current Study and Prior Research

Through analyzing the study results, conflicted findings and interesting facts of certain gamification strategies are revealed. Therefore, in this section, the effectiveness and mechanism of each gamification approach used in the thesis, along with participants' experience, are compared with prior critical studies such as *Fish'n'Step*, *UbiFit Garden*, *StepByStep*, and so on. Although there are some contradictory effects shown regarding certain gamification approaches, the reasons that caused it may be extracted via comparisons. What was learned from the comparisons can be used as design guidelines and principles for other researchers who build and investigate behaviour-changing prototypes. The importance of understanding how the contradictory effects were generated is not to judge which method is wrong or right. Rather, it is to figure out the context and prerequisites of what gamification strategy should be deployed, how to use it, and when. Table 6.1 shows the details of the prototypes discussed in this thesis, along with their differences compared to the research prototypes. Such analyses may enable researchers to develop more nuanced and in-depth understandings of gamification.

Goal-setting

Overall, for all 23 participants in this study, goal-setting was not considered as effective in providing motivation for physical activity as shown in prior research. Many applications have implemented goal-setting as a design strategy to promote activity. For example, in *Houston* (Consolvo et al. 2006), goal-setting was implemented as a strategy and *some* participants reported that they were motivated by knowing their performance with respect to their goals. However, the researcher did not compare the control group with the 'personal group' (goal-setting group) or analyze the quantitative data collected from the pedometer device. Similarly, in *GoalPost* (Munson and Consolvo 2012), participants found it is beneficial to have primary and secondary goals to receive reminders for performing physical activity. In *StepByStep* (Zuckerman and Gal-Oz 2014), the researchers concluded from their first user study that offering continuous measurement of physical activity information and real-time feedback about one's progress towards ones' goal had a significantly higher activity level than the control group (without research prototype). Nevertheless, in both research studies, the researchers did not show evidences proof regarding either where the motivation came from in the real-time pop-up notifications or feedback of one's progress, or the goal per se. It could be that the enhanced self-reflection and self-awareness took effect in promoting activities.

Compared to research prototypes like *GoalPost*, *Houston* and *StepByStep*, in this thesis, first, all participants were given goal-setting as a study task, and second, their behaviours were observed over a longer period of time. From the results of this thesis study, I learned that even though participants were allowed to set multiple and adjustable goals knowing their baseline activity level: (1) some people still encounter problems of finding appropriate goals; this was not mentioned or discussed in prior studies and (2) other individuals experienced complicated life situations such as family obligations, work responsibilities and so on and thus could not complete goals on some days, even though they tried hard. So it is fair to argue that goal-setting as a gamification strategy can be an effective approach to promote motivation ONLY under certain circumstances. Moreover, the difficulty of the goal should be challenging but should still match one's capability to attain it. More importantly, what to set as the activity goal varies a lot with regard to personal contexts. In conclusion, when it comes to determining which goals to maintain, the personal life context mattered to individuals, and this situation goes far beyond the solution of 'setting primary or secondary goals' can achieve. When designing goal-setting as a gamification strategy, one's background needs to be taken into consideration, and proper and professional advice is important to the effectiveness of such strategy.

Social Interaction

Social components that have been implemented in applications for lifestyle improvement are one of the most effective approaches so far. This was demonstrated in *Houston* and *StepStream*, where participants who experienced the social features had more physical activity and more progress towards their goals. Yet, in other studies like *Fish'n'Step*, *GoalPost*, and *StepByStep*, a contradictory result of social strategies was found. Participants in these study groups generally reported negative feelings and privacy concerns about sharing personal information and having social interaction with others.

In a close scrutiny of how the social interaction happened, two different mechanisms of communication and collaboration were identified from both prior studies and the second user study in this thesis. One type of mechanism is passive involvement. In *Fish'n'Step* and *StepByStep,* participants interacted with strangers who they know nothing about, and their physical activity data were ranked together in a public digital leaderboard. In *GoalPost*, participants shared their activity information on Facebook. In these situations, individuals maintain a passive way of communicating within the study group or with others outside the group: no real-time collaboration or synchronous feedback and no actual social interaction was going on. The other type of social interaction is more active: dynamic communication and collaboration were going on, especially when acquaintances were involved. In studies like *Houston* and *StepStream*, people engaged with the social interaction that the prototype allowed, most likely because the ones they were following were mainly their friends, instead of strangers, as the research papers mentioned,.

In this thesis, the *FitBit* Website Community involved participants passively, but the *FitBit* Mobile Challenge engaged them in a more active way. By investigating two types of social interaction – via the Website Community and the Mobile Challenge – I realized people engaged better when there was an active approach of communication and collaborations through social interaction afforded by the apparatus. For instance, participants in the social group perceived the Website Community to be less engaging and gave negative feedback regarding social interaction, whereas participants reported that the Mobile Challenge was fun and engaging mainly because (1) they had the actual real-time synchronous communication with other members in the group; (2) besides peer-competition, "peer-cheer" through live chat window was deemed to be encouraging and helpful; (3) the group size (8 people) was within an appropriate amount to sustain connectivity and emotional engagement with others.

Obviously, as learned from the study interviews, continuous emotional engagement is the key to sustaining an individual's engagement and keeping an individual motivated for a long-term behavior change. According to the comparisons of prior research studies, *what social interaction mechanisms are deployed* (passive communication like the Website Community or active collaboration like the Mobile Challenge), *who are in the group*, and *how large the group is* are three critical factors necessary to maintain people's social connectivity with others; this in turn determines the effectiveness of the social interaction strategy.

Virtual Avatar

Virtual avatars — such as the virtual fish in *Fish'n'Step* and virtual flowers in *UbiFit Garden* — have been implemented in research prototypes to a) represent physical activity data as a design strategy which b) can in turn cultivate the internal emotional link between the virtual avatar and the individual.

However, in *Fish'n'Step*, this intervention was not successful in fostering participants' empathy of the virtual fish. Fish'n'Step seems to have lost the original design intent – using the virtual avatar as an incentive to promote activity. But in *UbiFit Garden*, the virtual flower worked effectively in presenting the users' data and promoting users' activity. The differences are that *UbiFit Garden* presented participants' data through a glanceable mobile display as the background wallpaper, but *Fish'n'Step* presented participants' data on a public shared screen. Therefore, virtual flowers reminded participants of their progress towards goals and provided an awareness of their physical activity conditions way more frequently than the virtual fish did.

Prior virtual avatars have worked as a one-way information projection, where people observe the virtual avatar's changes, and these changes represent the subject's physical activity conditions. Therefore, based on what was learned from *Fish'n'Step* and *UbiFit Garden* prototypes, *FitPet* was built as an interactive mobile game that has a two-way interaction tool. On one hand, the virtual avatar displays the physical activity data visualization in an abstract way. On the other hand, the virtual avatar requires players' attention and physical effort to stay alive and healthy.

From both the quantitative activity data and the qualitative interviews, it was proved that *FitPet* was not a very effective way to promote activity as an incentive. The major problem was that when I translated the relationship between individual's physical activity condition and the digital pet's condition in the game, I failed to consider and implement the game flow theory – match the player's skill with the game's challenges. The experimental results in this thesis reveal that even a small-scale game such as *FitPet* requires keeping players' flow, constant emotional engagement and investment.

Besides lack of game flow, compared to *UbiFit Garden* (which is one of the most effective 'virtual avatar-ization' gamification strategies), participants in this study did not report an enhanced sense of self-awareness or self-reflection of their personal physical conditions. This is likely because *FitPet* was designed as an interactive mobile game instead of the mobile phone's wallpaper; thus, it requires extra attention and motivation to open the game application. Although it seems more fun to play the game and does not take much effort to operate the *FitPet* mobile application, users cannot unconsciously attend to it, as they can with ambient wallpaper.

For future interactive games designed for behavior changes like *FitPet*, more real-time feedback, like pop-up notifications, are necessary to increase self-awareness of one's physical conditions. More importantly, the gameplay should follow the game flow theory and keep players within the flow channel.

Research Prototype	Gamification Approaches	User Study	Detailed Features
Fish'n'Step (Lin et al. 2006)	Social Interaction (passive leaderboard), Virtual Avatar	14 weeks, n=19; with pre-, test and post-test phases	Animated virtual fish in a public display, no personal mobile access. Has social competition, but no real-time response or other social interaction.
Houston (Consolvo et al.	Goal-setting, Social Interaction (share and	3 weeks, n = 13; no pre- or post-test	Mobile App, without virtual pet avatar, no real-time

2006)	request activity data)	observations	communication and/or collaboration.
UbiFit Garden (Consolvo et al. 2008)	Goal-setting, Virtual Avatar	3 weeks, n = 12; no pre- or post-test observation	Glanceable display with virtual flower representation in mobile phone, non-interactive game, no social interaction.
GoalPost (Munson and Consolvo 2012)	Goal-setting, Social Interaction (passive post)	4 week, n = 23; no pre- or post-test observation	Social sharing of activity data through Facebook post, no social interaction.
StepByStep (Zuckerman and Gal-Oz 2014)	Goal-setting, Social Interaction (passive leaderboard)	First study: 2 weeks, n = 40; Second study: 10 days, n = 59; no pre- or post-test observation	Social sharing of only activity data through mobile App, no real-time communication or other social interaction
StepStream (Miller and Mynatt 2014)	Social Interaction (website community)	4 weeks, n =42; no pre- or post-test observation	Social sharing through website community, with asynchronous communication.
FitPet (in this thesis)	Goal-setting, Virtual Avatar, Interactive Game	6 weeks, n = 8; with pre-, test and post-test phases	Mobile game representing physical activity data using virtual pet's health condition
FitBit Website Community and	Goal-setting, Social interaction	6 weeks, n = 8 with pre-, test and post-	Social interaction through website

Mobile Challenge (in this thesis)		test phases	community and mobile challenge (FitBit applications)

Table 6.1 Comparisons with Prior Research Prototypes

Chapter 7. Conclusions and Future Work

7.1. Conclusions

In this thesis, I conducted two user studies and designed the research prototype for promoting users' physical activity. In the first study, I focused on the information visualization aspects of representing physical activity. Twenty-two participants joined the study and were given a task with three different visualizations: a bar chart, ringmap graph, and gamification visualizations were presented. Results showed that although the traditional bar chart visualization is more effective for understanding information and self-reflection, participants gave a higher rating to the *FitPet* visualization, and were fond of using a virtual pet's behavior to represent their physical activity level. Therefore, I designed and developed the *FitPet* mobile application to further investigate the design challenges and opportunities of such a game-based approach.

In the second user study, a six-week long field study was conducted with 23 participants. a) A *FitBit* and a goal-setting task were given to the control group. b) The first experimental group, the social group, was invited to a study activity group online, and were asked to engage with the group and a type of event called "challenges" with others. c) For the third study group, participants were asked to play a virtual pet-keeping game called *FitPet* and to keep the pet healthy. The game could convert steps into game coins that allow them to buy stuff and play games.

Comparing the three groups (control, social, and *FitPet* groups), the following conclusions could be drawn. First, that social interaction and social Challenges in particular were the most effective interventions for promoting more physical activity and steps. Whereas second, the game-based *FitPet* method did not work as effectively as expected because of reasons such as a lack of timely feedback, the lack of challenging gameplay and the lack of virtual pet interaction. Nevertheless, third, the participants considered this game-based approach to be an interesting and promising one. Fourth, the goal-setting task was not perceived as an effective way to provide motivations compared to social interaction overall.

From the second study, I learned that many factors contributed to the challenges of maintaining a healthy lifestyle and physical activity improvements. As categorized by Orzano et al. (Orzano and Scott 2004), some factors are ***economic***, such as busy daily work routine and family obligations, the availability and cost of health foods or the cost of joining a health club and the time required to regularly exercise. Others are ***psychological***, for example, depression and a lack of motivation to follow a healthier lifestyle every day when the improvements are only slowly noticeable. Others are ***social***, including the desire to fit in with one's existing social circles that engage in their own unhealthy behaviours. However, those factors are also what we can utilize in designing technologies for promoting instead of prohibiting physical activity and healthy behaviours.

Emotional engagement plays a significant role in motivating individuals as well as to keep them checked in and to stay motivated. The social aspects are evaluated as an effective strategy if used properly, and under certain circumstances. For example, some social aspects can involve participants in an **active** and engaging way, such as socializing and having fun with each other. Conversely, the **passive** communication afforded in the Website Community has not proven very effective in promoting physical activity. Moreover, besides social competition, opportunities for positive collaborations should be considered as an important type of social interaction when designing for gamification.

7.2. Future work

The lessons learned from the development of this research prototype and its field study could inform the design of applications for promoting physical activity or behavior changes. The users' needs and how various gamified approaches performed are also highlighted for future research. Specifically, social components should be implemented into a *FitPet-like* gamification approach, and its effectiveness should be investigated and evaluated. More mechanics and dynamics are needed in order to enhance the level of user awareness and engagement. Attending to these issues will help in the ways in which ubiquitous and persuasive technologies can be used to encourage physical activity and promote healthy behaviour changes.

The TTM theory worked at a meta-level in assisting this researcher in how to grapple with the aspect of motivation. Specifically, TTM provided a way to frame the stages of motivation and behaviour change, and to determine which motivational stages the participants were in for the study. Thus, TTM also helped in evaluating the prototypes' effectiveness, and to what degree the gamification approach encouraged the participant. In future work, however, combining the TTM theory more closely with the design approaches may lead to new and finer-grained findings.

In future work, I plan to dig deeper into my current quantitative and qualitative study data, as such an investigation may provide more detailed and nuanced understandings of gamification approaches. In addition, future work will focus on how different gamified methods and gamified systems can affect self-awareness and sustained behavior changes in the long-term.

References

Ahtinen, Aino, Pertti Huuskonen, and Jonna Häkkilä. 2010. “Let’s All Get Up and Walk to the North Pole: Design and Evaluation of a Mobile Wellness Application.” In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, 3–12. NordiCHI ’10. New York, NY, USA: ACM. doi:10.1145/1868914.1868920.

Ali, S.S.M., and B. George. 2012. “A Portable Pedometer Based on Inductive Proximity.” In *2012 15th International IEEE Conference on Intelligent Transportation Systems (ITSC)*, 1858–61. doi:10.1109/ITSC.2012.6338844.

Antin, J., and EF Churchill. 2011. “Badges in Social Media: A Social Psychological Perspective.” In .

Baranowski, Tom, Richard Buday, Debbe I. Thompson, and Janice Baranowski. 2008. “Playing for Real: Video Games and Stories for Health-Related Behavior Change.” *American Journal of Preventive Medicine* 34 (1): 74–82.e10. doi:10.1016/j.amepre.2007.09.027.

Björk, Staffan, Jussi Holopainen, Peter Ljungstrand, and Karl-Petter \AAkesson. 2002. “Designing Ubiquitous Computing Games – A Report from a Workshop Exploring Ubiquitous Computing Entertainment.” *Personal Ubiquitous Comput.* 6 (5-6): 443–58. doi:10.1007/s007790200048.

Bravata, Dena M., Crystal Smith-Spangler, Vandana Sundaram, Allison L. Gienger, Nancy Lin, Robyn Lewis, Christopher D. Stave, Ingram Olkin, and John R. Sirard. 2007. “Using Pedometers to Increase Physical Activity and Improve Health: A Systematic Review.” *JAMA* 298 (19): 2296–2304. doi:10.1001/jama.298.19.2296.

Brown, Tim. 2008. *Design Thinking*. Vol. 86. Harvard business review.

Burke, Brian. 2014. *Gamify: How Gamification Motivates People to Do Extraordinary Things*. 1937134857. Bibliomotion.

"CDC - Facts - Data - Physical Activity - DNPAO." 2015. Accessed August 4. http://www.cdc.gov/physicalactivity/data/facts.html.

Chan, Catherine B., Daniel A. J. Ryan, and Catrine Tudor-Locke. 2004. "Health Benefits of a Pedometer-Based Physical Activity Intervention in Sedentary Workers." *Preventive Medicine* 39 (6): 1215–22. doi:10.1016/j.ypmed.2004.04.053.

Chloe Fan, Jodi Forlizzi. 2012. "A Spark of Activity: Exploring Informative Art as Visualization for Physical Activity," 81–84. doi:10.1145/2370216.2370229.

Consolvo, Sunny, Katherine Everitt, Ian Smith, and James A. Landay. 2006. "Design Requirements for Technologies That Encourage Physical Activity." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 457–66. CHI '06. New York, NY, USA: ACM. doi:10.1145/1124772.1124840.

Consolvo, Sunny, Predrag Klasnja, David W. McDonald, and James A. Landay. 2009. "Goal-Setting Considerations for Persuasive Technologies That Encourage Physical Activity." In *Proceedings of the 4th International Conference on Persuasive Technology*, 8:1–8:8. Persuasive '09. New York, NY, USA: ACM. doi:10.1145/1541948.1541960.

Consolvo, Sunny, David W. McDonald, Tammy Toscos, Mike Y. Chen, Jon Froehlich, Beverly Harrison, Predrag Klasnja, et al. 2008. "Activity Sensing in the Wild: A Field Trial of Ubifit Garden." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1797–1806. CHI '08. New York, NY, USA: ACM. doi:10.1145/1357054.1357335.

Dallow, Cindy Byfield, and Jennifer Anderson. 2003. "Using Self-Efficacy and a Transtheoretical Model to Develop a Physical Activity Intervention for Obese Women." *American Journal of Health Promotion: AJHP* 17 (6): 373–81.

Deterding, S. 2011. "Situated Motivational Affordances of Game Elements: A Conceptual Model." In .

Deterding, Sebastian. 2015. “The Lens of Intrinsic Skill Atoms: A Method for Gameful Design.” *Human-Computer Interaction* 30 (3-4): 294–335. doi:10.1080/07370024.2014.993471.

Deterding, Sebastian, Dan Dixon, Rilla Khaled, and Lennart Nacke. 2011. “From Game Design Elements to Gamefulness: Defining ‘Gamification.’” In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9–15. MindTrek ’11. New York, NY, USA: ACM. doi:10.1145/2181037.2181040.

DiClemente, C. C., J. O. Prochaska, S. K. Fairhurst, W. F. Velicer, M. M. Velasquez, and J. S. Rossi. 1991. “The Process of Smoking Cessation: An Analysis of Precontemplation, Contemplation, and Preparation Stages of Change.” *Journal of Consulting and Clinical Psychology* 59 (2): 295–304.

Drobics, Mario, and Stuart Smith. 2014. “Game-Based IT Solutions for Active and Healthy Aging.” In *Games for Training, Education, Health and Sports*, edited by Stefan Göbel and Josef Wiemeyer, 8–11. Lecture Notes in Computer Science 8395. Springer International Publishing. http://link.springer.com.proxy.lib.sfu.ca/chapter/10.1007/978-3-319-05972-3_2.

Epstein, Leonard H., Meghan D. Beecher, Jennifer L. Graf, and James N. Roemmich. 2007. “Choice of Interactive Dance and Bicycle Games in Overweight and Nonoverweight Youth.” *Annals of Behavioral Medicine : A Publication of the Society of Behavioral Medicine* 33 (2): 124–31. doi:10.1080/08836610701307835.

Ferrucci, L., S. Baldasseroni, S. Bandinelli, W. de Alfieri, A. Cartei, D. Calvani, A. Baldini, G. Masotti, and N. Marchionni. 2000. “Disease Severity and Health-Related Quality of Life across Different Chronic Conditions.” *Journal of the American Geriatrics Society* 48 (11): 1490–95.

Goh, Dion H., and Chei Sian Lee. 2011. “Perceptions, Quality and Motivational Needs in Image Tagging Human Computation Games.” *J. Inf. Sci.* 37 (5): 515–31. doi:10.1177/0165551511417786.

Hardeman, W., S. Griffin, M. Johnston, A. L. Kinmonth, and N. J. Wareham. 2000. “Interventions to Prevent Weight Gain: A Systematic Review of Psychological Models and

Behaviour Change Methods.” *International Journal of Obesity and Related Metabolic Disorders: Journal of the International Association for the Study of Obesity* 24 (2): 131–43.

Intille, Stephen S. 2004. “Ubiquitous Computing Technology for Just-in-Time Motivation of Behavior Change.” *Studies in Health Technology and Informatics* 107 (Pt 2): 1434–37.

Jafarinaimi, Nassim, Jodi Forlizzi, Amy Hurst, and John Zimmerman. 2005. “Breakaway: An Ambient Display Designed to Change Human Behavior.” In *CHI ’05 Extended Abstracts on Human Factors in Computing Systems*, 1945–48. CHI EA ’05. New York, NY, USA: ACM. doi:10.1145/1056808.1057063.

Konkel, Miriam, Vivian Leung, Brygg Ullmer, and Catherine Hu. 2004. “Tagaboo: A Collaborative Children’s Game Based Upon Wearable RFID Technology.” *Personal Ubiquitous Comput.* 8 (5): 382–84. doi:10.1007/s00779-004-0302-y.

Langer, Ellen J., and Judith Rodin. 1976. “The Effects of Choice and Enhanced Personal Responsibility for the Aged: A Field Experiment in an Institutional Setting.” *Journal of Personality and Social Psychology* 34 (2): 191–98. doi:10.1037/0022-3514.34.2.191.

Larsen, Jakob Eg, Andrea Cuttone, Sune Lehmann Jørgensen, Jakob Eg Larsen, Andrea Cuttone, and Sune Lehmann Jørgensen. 2013. “QS Spiral: Visualizing Periodic Quantified Self Data.” *Proceedings of CHI 2013 Workshop on Personal Informatics in the Wild: Hacking Habits for Health & Happiness*.

Lieberman, D. A. 1997. “Interactive Video Games for Health Promotion: Effects on Knowledge, Self-Efficacy, Social Support, and Health.”

Lin, James J., Lena Mamykina, Silvia Lindtner, Gregory Delajoux, and Henry B. Strub. 2006. “Fish’n’Steps: Encouraging Physical Activity with an Interactive Computer Game.” In *UbiComp 2006: Ubiquitous Computing*, edited by Paul Dourish and Adrian Friday, 261–78. Lecture Notes in Computer Science 4206. Springer Berlin Heidelberg. http://link.springer.com/chapter/10.1007/11853565_16.

Logan, Beth, Jennifer Healey, Matthai Philipose, Emmanuel Munguia Tapia, and Stephen Intille. 2007. “A Long-Term Evaluation of Sensing Modalities for Activity Recognition.” In *Proceedings of the 9th International Conference on Ubiquitous Computing*, 483–500. UbiComp ’07. Berlin, Heidelberg: Springer-Verlag. http://dl.acm.org/citation.cfm?id=1771592.1771620.

Marshall, S. J., and S. J. Biddle. 2001. “The Transtheoretical Model of Behavior Change: A Meta-Analysis of Applications to Physical Activity and Exercise.” *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine* 23 (4): 229–46.

McCallum, Simon. 2012. “Gamification and Serious Games for Personalized Health.” *Studies In Health Technology And Informatics* 177: 85–96.

McGonigal, Jane. 2011. *Reality Is Broken: Why Games Make Us Better and How They Can Change the World*. Random House.

McLean, N., S. Griffin, K. Toney, and W. Hardeman. 2003. “Family Involvement in Weight Control, Weight Maintenance and Weight-Loss Interventions: A Systematic Review of Randomised Trials.” *International Journal of Obesity and Related Metabolic Disorders: Journal of the International Association for the Study of Obesity* 27 (9): 987–1005. doi:10.1038/sj.ijo.0802383.

Mekler, Elisa D., Florian Brühlmann, Klaus Opwis, and Alexandre N. Tuch. 2013. “Disassembling Gamification: The Effects of Points and Meaning on User Motivation and Performance.” In *CHI ’13 Extended Abstracts on Human Factors in Computing Systems*, 1137–42. CHI EA ’13. New York, NY, USA: ACM. doi:10.1145/2468356.2468559.

Michie, Susan, Charles Abraham, Craig Whittington, John McAteer, and Sunjai Gupta. 2009. “Effective Techniques in Healthy Eating and Physical Activity Interventions: A Meta-Regression.” *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association* 28 (6): 690–701. doi:10.1037/a0016136.

Miller, Andrew D., and Elizabeth D. Mynatt. 2014. “StepStream: A School-Based Pervasive Social Fitness System for Everyday Adolescent Health.” In *Proceedings of the SIGCHI*

Conference on Human Factors in Computing Systems, 2823–32. CHI ’14. New York, NY, USA: ACM. doi:10.1145/2556288.2557190.

Mokka, Sari, Antti Väätänen, Juhani Heinilä, and Pasi Välkkynen. 2003. “Fitness Computer Game with a Bodily User Interface.” In *Proceedings of the Second International Conference on Entertainment Computing*, 1–3. ICEC ’03. Pittsburgh, PA, USA: Carnegie Mellon University. http://dl.acm.org/citation.cfm?id=958720.958729.

Munson, S.A., and S. Consolvo. 2012. “Exploring Goal-Setting, Rewards, Self-Monitoring, and Sharing to Motivate Physical Activity.” In *2012 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, 25–32.

National Center for Health Statistics (US). 2005. *Health, United States, 2005: With Chartbook on Trends in the Health of Americans*. Health, United States. Hyattsville (MD): National Center for Health Statistics (US). http://www.ncbi.nlm.nih.gov/books/NBK20990/.

Nicholson, S. 2012. “A User-Centered Theoretical Framework for Meaningful Gamification.”

Obi, Toshio, Diana Ishmatova, and Naoko Iwasaki. 2013. “Promoting ICT Innovations for the Ageing Population in Japan.” *International Journal of Medical Informatics* 82 (4): e47–62. doi:10.1016/j.ijmedinf.2012.05.004.

Orzano, A. John, and John G. Scott. 2004. “Diagnosis and Treatment of Obesity in Adults: An Applied Evidence-Based Review.” *The Journal of the American Board of Family Practice / American Board of Family Practice* 17 (5): 359–69.

Pate, Russell R., Pratt Michael, Blair Steven N., Haskell Wiliam L., Macera Caroline A., Bouchard Claude, and Buchner David. 1995. “Physical Activity and Public Health: A Recommendation From the Centers for Disease Control and Prevention and the American College of Sports Medicine” 273 (5): 402–7.

Pekkanen, Juha, Aulikki Nissinen, Bernard Marti, Jaakko Tuomilehto, Sven Punsar, and MarttiJ. Karvonen. 1987. “REDUCTION OF PREMATURE MORTALITY BY HIGH

PHYSICAL ACTIVITY: A 20-YEAR FOLLOW-UP OF MIDDLE-AGED FINNISH MEN." *The Lancet*, Originally published as Volume 1, Issue 8548, 329 (8548): 1473–77. doi:10.1016/S0140-6736(87)92218-5.

Pentney, William, Ana-Maria Popescu, Shiaokai Wang, and Henry Kautz. n.d. *Sensor-Based Understanding of Daily Life via Large-Scale Use of Common Sense*.

Pink, Daniel H. 2011. *Drive: The Surprising Truth About What Motivates Us*. Reprint edition. Riverhead Books.

Ploderer, Bernd, Wolfgang Reitberger, Harri Oinas-Kukkonen, and Julia van Gemert-Pijnen. 2014. "Social Interaction and Reflection for Behaviour Change." *Personal and Ubiquitous Computing* 18 (7): 1667–76. doi:10.1007/s00779-014-0779-y.

Prochaska, James O., and Wayne F. Velicer. 1997. "The Transtheoretical Model of Health Behavior Change." *American Journal of Health Promotion* 12 (1): 38–48. doi:10.4278/0890-1171-12.1.38.

Przybylski, Andrew K., C. Scott, and Richard M. Ryan. 2010. "A Motivational Model of Video Game Engagement." *Review of General Psychology* 14 (2): 154–66. doi:10.1037/a0019440.

Ralph Maddison, Cliona Ni Mhurchu, Andrew Jull, Yannan Jiang, Harry Prapavessis, and Anthony Rodgers. 2007. "Energy Expended Playing Video Console Games: An Opportunity to Increase Children's Physical Activity?" *Pediatric Exercise Science* 19 (3): 334–43.

"Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin." 2002. *New England Journal of Medicine* 346 (6): 393–403. doi:10.1056/NEJMoa012512.

Riebe, Deborah, Bryan Blissmer, Geoffrey Greene, Marjorie Caldwell, Laurie Ruggiero, Kira M. Stillwell, and Claudio R. Nigg. 2005. "Long-Term Maintenance of Exercise and Healthy Eating Behaviors in Overweight Adults." *Preventive Medicine* 40 (6): 769–78. doi:10.1016/j.ypmed.2004.09.023.

Schön, Donald A. 1983. *The Reflective Practitioner: How Professionals Think in Action*. Basic Books.

Slattery, Martha L., and John D. Potter. 2002. “Physical Activity and Colon Cancer: Confounding or Interaction?” *Medicine and Science in Sports and Exercise* 34 (6): 913–19.

Taylor, C B, J F Sallis, and R Needle. 1985. “The Relation of Physical Activity and Exercise to Mental Health.” *Public Health Reports* 100 (2): 195–202.

Terra, Rui, Lino Figueiredo, Ramiro Barbosa, and Ricardo Anacleto. 2013. “Step Count Algorithm Adapted to Indoor Localization.” In *Proceedings of the International C* Conference on Computer Science and Software Engineering*, 128–29. C3S2E ’13. New York, NY, USA: ACM. doi:10.1145/2494444.2494457.

Thompson, Paul D., David Buchner, Ileana L. Piña, Gary J. Balady, Mark A. Williams, Bess H. Marcus, Kathy Berra, et al. 2003. “Exercise and Physical Activity in the Prevention and Treatment of Atherosclerotic Cardiovascular Disease A Statement From the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity).” *Circulation* 107 (24): 3109–16. doi:10.1161/01.CIR.0000075572.40158.77.

Toscos, Tammy, Anne Faber, Shunying An, and Mona Praful Gandhi. 2006. “Chick Clique: Persuasive Technology to Motivate Teenage Girls to Exercise.” In *CHI ’06 Extended Abstracts on Human Factors in Computing Systems*, 1873–78. CHI EA ’06. New York, NY, USA: ACM. doi:10.1145/1125451.1125805.

Tudor-Locke, Catrine. 2002. “Taking Steps toward Increased Physical Activity: Using Pedometers To Measure and Motivate.” *President’s Council on Physical Fitness and Sports Research Digest*, June. http://eric.ed.gov/?id=ED470689.

Tudor-Locke, Catrine E., Anita M. Myers, Rhonda C. Bell, Stewart B. Harris, and N. Wilson Rodger. 2002. “Preliminary Outcome Evaluation of the First Step Program: A Daily Physical Activity Intervention for Individuals with Type 2 Diabetes.” *Patient Education and Counseling* 47 (1): 23–28.

Vuori, I. M. 2001. “Dose-Response of Physical Activity and Low Back Pain, Osteoarthritis, and Osteoporosis.” *Medicine and Science in Sports and Exercise* 33 (6 Suppl): S551–86; discussion 609–10.

Wing, R. R., and J. O. Hill. 2001. “Successful Weight Loss Maintenance.” *Annual Review of Nutrition* 21: 323–41. doi:10.1146/annurev.nutr.21.1.323.

Xu, Yan, Erika Shehan Poole, Andrew D. Miller, Elsa Eiriksdottir, Richard Catrambone, and Elizabeth D. Mynatt. 2012. “Designing Pervasive Health Games for Sustainability, Adaptability and Sociability.” In *Proceedings of the International Conference on the Foundations of Digital Games*, 49–56. FDG ’12. New York, NY, USA: ACM. doi:10.1145/2282338.2282352.

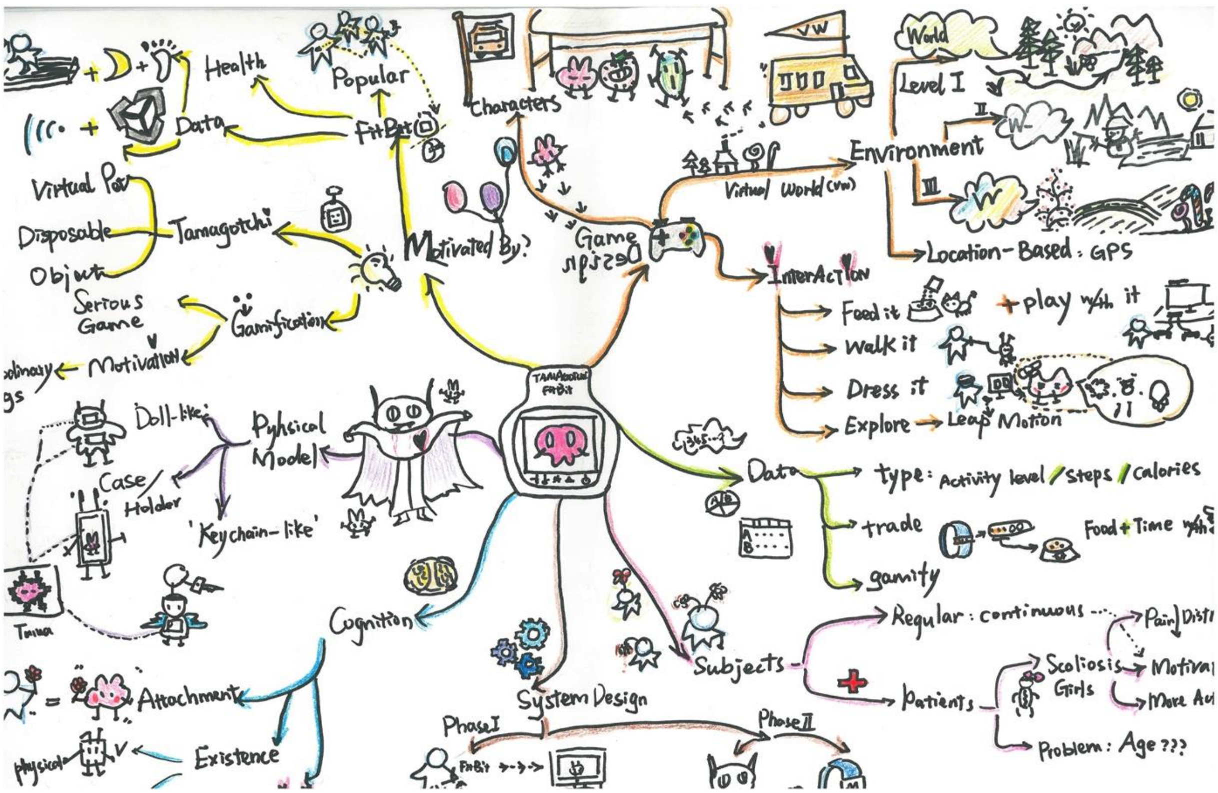
Zhao, Neil. 2010. “Full-Featured Pedometer Design Realized with 3-Axis Digital Accelerometer” 44 (6).

Zuckerman, Oren, and Ayelet Gal-Oz. 2014. “Deconstructing Gamification: Evaluating the Effectiveness of Continuous Measurement, Virtual Rewards, and Social Comparison for Promoting Physical Activity.” *Personal and Ubiquitous Computing* 18 (7): 1705–19. doi:10.1007/s00779-014-0783-2.

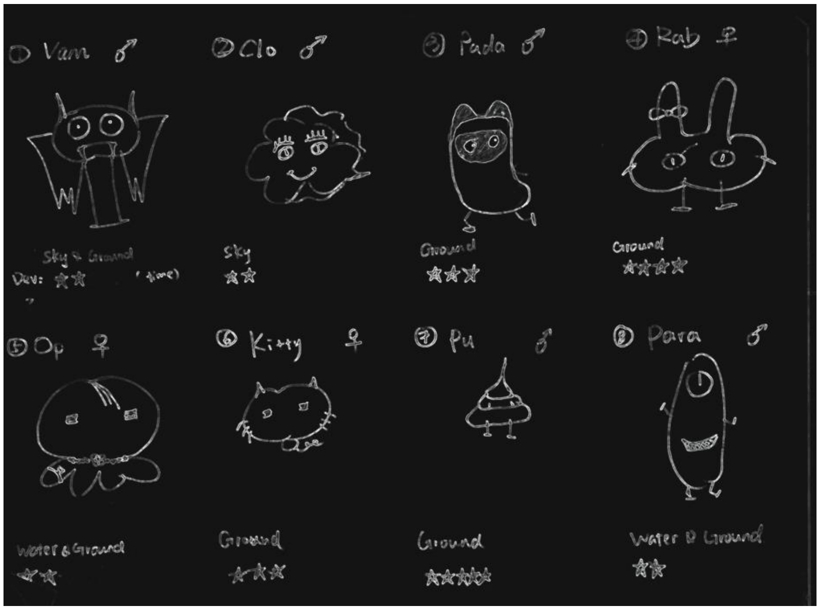
Appendix A.

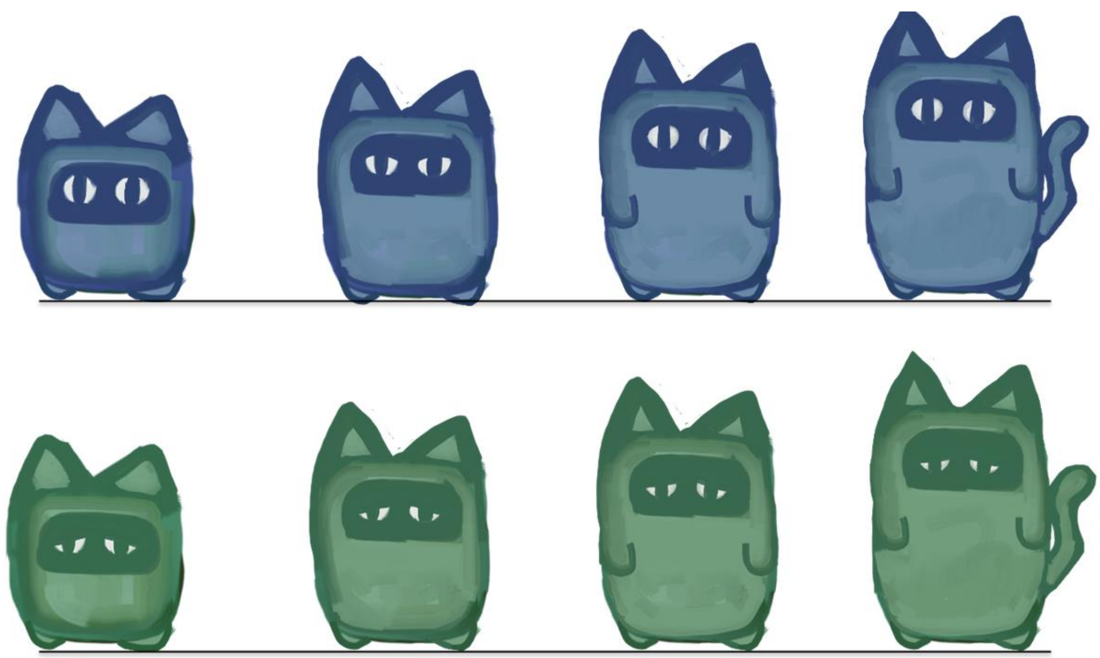
FitPet Game Design Sketches

1. Mind Map for the Gameplay Design

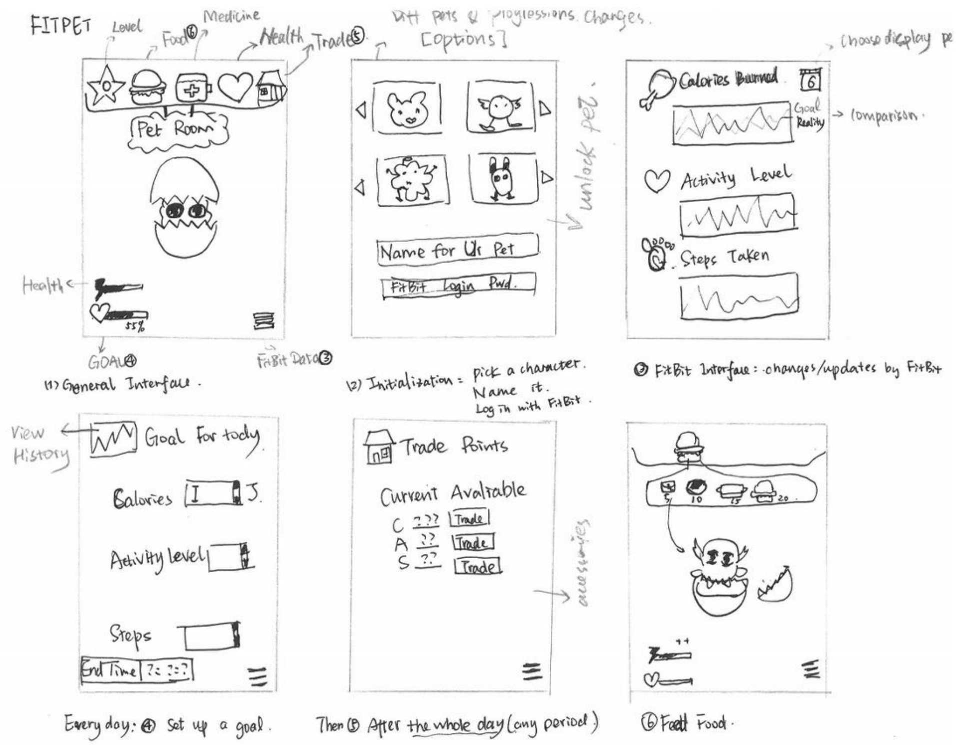


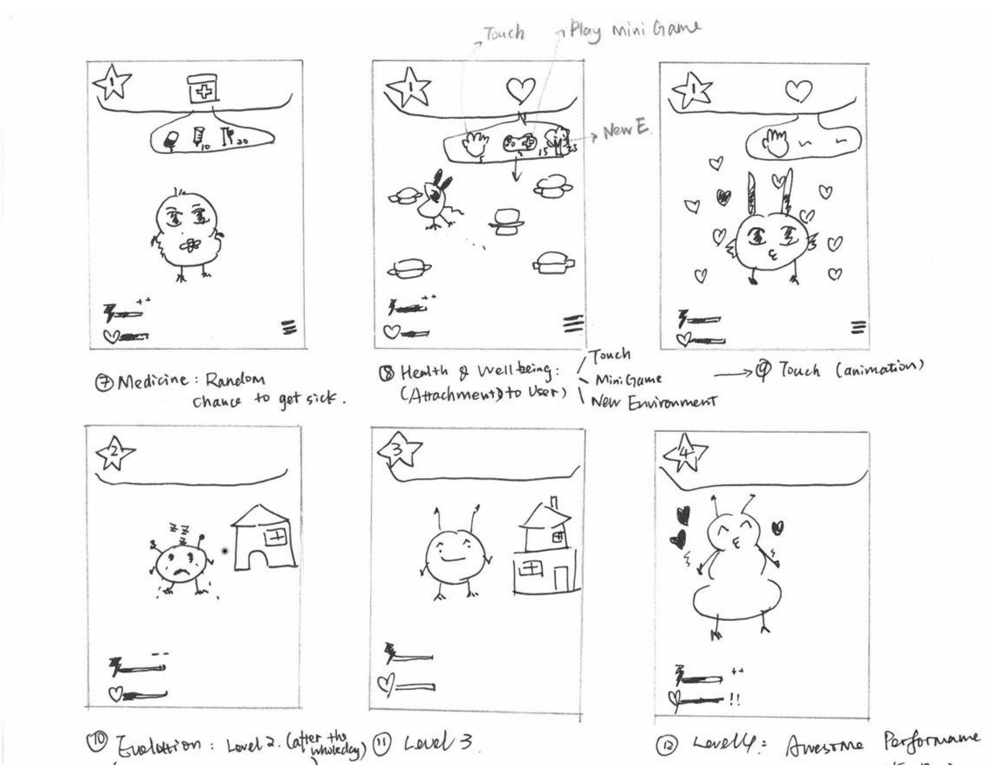
2. Characters Design and Alternate Digital Pet Option for the Virtual Pet





3. Mobile User Interface Design Sketches





Appendix B.

Study 2 Interview Scripts and Questionnaires during Three Phases

1. Pre-intervention Interview Script

Below questionnaire was for all three experimental groups:

(1) Have you ever think about your physical activity level before you participated the study, and after the first two weeks?

(2) How much do you think you understand your physical activity level and related data, like steps taken, calories consumption, and active levels?

(3) Have you ever actually do something about your physical activity before you participated the study, and after the first two weeks?

(4) Why this particular activity? How often do you go to exercise? Which type of exercise do you do?

(5) Is there a reason driven you to be physically active? What is it? (Wellbeing, build muscle, hobby, habit, daily routine, and so on)

(6) Do you think your current physical activity level is enough to keep you in a good health?

(7) What is the main reason stopping you from participating in any physical activity or exercises, time, money, or energy? What do you think could impact you from being active?

(8) If you keep regular exercise, do you ever feel lack of motivation to keep long-term* exercise? *Long-term: an activity that you keep doing frequently more than 1 month.

(9) Do you have any goals for being active or taking exercise? What is your goal? Is it long-term or short-term? Have you already paid any effort to achieve your goal?

(10) Do you want to increase, keep balance, or decrease your activity level?

(11) Have you ever self-reflect on your physical activity? Do you use wearable, mobile APPs or other tool to help you? How do you reflect on your data? What do you learn from your data?

(12) Do you self-tracking or collecting your activity data before the study? If yes, then what type of data are you collecting?

(13) If yes to question 12, then what tool are you using to collect such data? (*FitBit*, Jawbone, Mint, Nike+, Watton, and so on)

(14) If yes to question 12, then what tools do you use for personal informatics: laptop, mobile devices, notebooks or the wearable device itself? Do you use any software or data visualization tool?

(15) How often do you check your data? Is there anything that you are looking for from your data? Do you compare your data collected from different time?

(16) Do you have any questions about your data? Do you want to answer specific questions so that you keep monitoring your data?

(17) If your answer is YES to the last question, then WHY do you have such question? Could you answer your questions with your data-tracking tool? HOW? What problem do you experience while trying to answer your questions?

(18) Do you feel that you have any changes before and after you use such tool to reflect your data, in terms of behavior changes due to data collecting and self-reflection?

2. Intervention Interview Script

2.1 Below questions were used in the control group:

(1) Do you feel that you have any changes on physical activity before goal-setting?

(2) Does goal-setting promote/encourage more steps?

(3) Does *FitBit* help with achieving your goal? Why and How?

(4) Have you self-reflected on your physical activity level or the data from *FitBit* dashboard summary? What do you learn from your self-reflection?

(5) Does such self-reflection or self-tracking help you with setting up goals? Does it help with encouraging or motivating more physical activity?

(6) Any particular data that you would like to self-reflect on and ask a question for? Do you think the data you reflect on will motivate you to keep exercise/be active or be more active?

(7) Do you have any change in your physical activity because of the self-monitoring or the goal-setting task?

2.2 Below questions were used in the Social Community group:

(1) Does the goal-setting promote/encourage more steps or physical activity?

(2) Does *FitBit* help with achieving your goal? How?

(3) How often do you check the online activity community group and how do you feel about it, such as the leaderboard, the discussion area, and the rankings?

(4) Do you get motivated or promoted to have more activities because of the activity group?

(5) Have you ever tried the Challenges at your mobile phone? How was the experience? Do you think that is helpful for encouraging activities?

(6) Do you communicate or social networking with your friends/other participants from the group?

(7) Have you ever self-reflecting on your physical activity level or the data with the help with *FitBit* dashboard information visualization? What do you learn from your self-reflection?

(8) Does such self-reflection or self-tracking help you with setting up goals? Does it help with encouraging more physical activity?

(9) Any particular data that you would like to self-reflect on and ask a question for?

(10) Do you think the data you reflect on will motivate you to keep exercise/be active or be more active?

(11) Do you have any change in your physical activity because of the *FitBit*, goal-setting, Activity Groups, or challenges from other participants?

2.3 Below questions were used in the FitPet mobile game group:

(1) How do you like the gameplay and interaction with this virtual pet-keeping game?

(2) How often do you check the virtual pet in your mobile every day?

(3) Do you feel you are engaged with this game? Do you build an emotional attachment to it? If yes, what components engaged you?

(4) Did you think the virtual pet could motivate you take more steps or enhance your physical activity every day? Why or why not?

(5) Is there anything about your physical activity that you have learned from the *FitPet* mobile game?

(6) Do you like to adopt such a virtual pet and associate your health with it?

(7) Do you think by associating your health data to a virtual pet in this game motivate your physical activity could provide you more motivation?

(8) Do you think to be more active because you want your virtual pet could grow up and be healthy?

(9) How do you like the design of the *FitPet* mobile game?

(10) How do you think of the gamified approach your health data?

(11) Comparing to the *FitBit* Dashboard, which one do you prefer to use to self-reflect?

(12) Do you set up any goal with *FitPet* during intervention? What is your goal and does *FitPet* help with achieving your goal?

(13) Do you have any change in your physical activity because of the *FitPet*?

(14) Other feedback or suggestion about the gameplay and the design of *FitPet*?

3. Post-intervention Interview Script

Below questionnaire was for all three experimental groups:

(1) Would you keep using it to track your data in the future? Why or why not? (For *FitPet* Group ONLY) Would you keep playing the game in the future? Why or why not?

(2) Do you feel it is a trouble to wear it all day for the past six weeks?

(3) Did you continue set up goals for yourself during the last two weeks like you did in the middle two weeks? Did you join any communities? Did you try other challenges?

(4) Do you feel that you have any changes, comparing to two weeks ago? Also comparing to before the study?

(5) Do you have any change in your physical activity because of the *FitBit*, the social group, or the *FitPet* game?

(6) What is your current motivation for being active?

(7) Do you think more self-reflection keep you motivated to stay active?

(8) Do you feel you have increased your physical activity level after participate the study? Do you want to increase or maintain or decrease your current level?

(9) Do you have any plan of how you will stay active after the study?

(10) How do you like the game idea that associating your health point with the game of keeping a virtual pet healthy?

(11) Any gamification idea you would have to promote/maintain an active level of physical activity?

4. Participants' Background Information Questionnaire

Below questionnaire was for all three experimental groups: answers were reported with numbers between 0 to 100 Visual Analog Scales

(1) How often do you think about your physical activity?

0 ____ 100

(2) How often do you actually DO something about your physical activity (like exercising)?

0 ____ 100

(3) How would you evaluate your daily activity level?

0 100

(4) Is there a trend/pattern (regular activity) in your daily activity that will influence your activity level? *Such as jogging at 7:00 am every morning, going to school/work at 9:00 am, and other regular activities

a) Yes b) No

What is this activity and when does this activity pattern usually happen? (List the activities and its time, for example, morning exercise – 7 am)

(5) How would you describe your computer and Internet use?

0 100

(6) How would you describe your cell phone use?

0 100

(7) How would you describe your wearable technology* use? Wearable technology*: clothing and accessories incorporating computer and advanced electronic technologies. The designs often incorporate practical functions and features, but may also have a purely critical or aesthetic agenda. For example, *FitBit*, *JawBone* and so on.

0 100

(8) How often do you play video games?

0 100

(9) How often do you play mobile games?

0 100

(10) Have you ever had a *Tamagotchi** or played similar PC/Mobile virtual pet-keeping game before? *Tamagotchi** is a Japanese-developed handheld digital pet game.

Most *Tamagotchi* are housed in a small egg-shaped computer with an interface usually consisting of buttons, which the pet could be fed and interact with.

a) Yes   b) No

(11) If you answered ‘yes’ to question 13, how often did you play with *Tamagotchi* each day?

a) Very Often   b) Usually   c) Sometimes   d) A few times   e) Not at all

(12) If you answered ‘yes’ to question 13, how long did you keep it?

5. Pre-intervention Questionnaire

Below questionnaire was for all three experimental groups:

(1) How often did you have *FitBit* with you during the past two weeks? (Be honest! :)

a) Everyday   b) 4-5 days/week   c) 2-3 days/week   d) 1 day/week   e) Never
f) If above frequency does not fit your condition:

(2) How often did you check your mobile *FitBit* application during the past two weeks?

a) Every 1-2 hour b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never
f) If above frequency does not fit your condition:

(3) How often did you check your *FitBit* website dashboard during the past two weeks?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never

f) If above frequency does not fit your condition:

(4) How often did you reflect upon your physical activity data based on the data from *FitBit* App/dashboard during the past two weeks?

a) Very Often b) Usually c) Sometimes d) A few times e) Not at all

f) If above frequency does not fit your condition:

(5) Does the physical activity data collected by *FitBit* help you with self-reflection?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all

f) If above frequency does not fit your condition:

(6) How would you evaluate the Readability of data visualization on the *FitBit* Dashboard? Very hard to read Very easy to read

0 100

(7) How would you evaluate the Comprehension of data visualization on the *FitBit* Dashboard?

Very hard to understand Very easy to understand

0 100

(8) How would you evaluate the Attractiveness of data visualization on the *FitBit* Dashboard?

Not attractive at all Very attractive

0 100

(9) How would you evaluate the Emotional Engagement with *FitBit* health tracker?

Not at all Very much

0 100

(10) How much awareness towards walking was heightened throughout the day because of the use of *FitBit*?

Not at all Very much

0 100

(11) To which degree would you perceive *FitBit* as an effective approach to promote your physical activity?

Very Ineffective Very effective

0 100

(12) Did you get any badges during the past two weeks? If yes, what are they?

List your badges awarded by *FitBit*:

(13) Select the Main Features of *FitBit* you have used during the past two weeks:

Website Dashboard Mobile Application Health Data Collection Sleep Data Collection Track Food Intake Track Water Intake Visualizations of physical activity (bar charts) Track Weight Join Community (Groups) Connect with friends Compete or Collaborate with friends Track your goal (LED dots) Make Food Pan Track Exercise Start Challenges Alarm Clock

Anything ELSE:

(14) How often do you think about your physical activity?

0 100

(15) How often do you actually DO something about your physical activity (like exercising)?

0 100

(16) How would you evaluate your daily activity level?

0 100

(17) Is there a trend/pattern (regular activity) in your daily activity that will influence your activity level? *Such as jogging at 7:00 am every morning, going to school/work at 9:00 am, and other regular activities

a) Yes b) No

(18) Is the activity trend/pattern the same as what you have mentioned two weeks ago?

a) Yes b) No

If no, then does this trend happen because of *FitBit* Health Tracker or another reason?

(19) What is this activity and when does this activity pattern usually happen?

(List the activities and its time, for example, morning exercise – 7 am)

(20) Do you set up personal goal for your regular physical activity?

a) Yes b) No

If yes, what is your goal?

6. Intervention Questionnaire

2.1 Below questions were used in the control group:

(1) How often did you have *FitBit* with you during Week 3 – Week 4? (Be honest! :)

a) Everyday b) 4-5 days/week c) 2-3 days/week d) 1 day/week e) Never

f) If above frequency does not fit your condition:

(2) How often did you check your mobile *FitBit* application during Week 3 – Week 4?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(3) How often did you check your *FitBit* website dashboard during Week 3 – Week 4?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(4) How often did you reflect upon your physical activity data based on the data from *FitBit* App/dashboard during Week 3 – Week 4?

a) Very Often b) Usually c) Sometimes d) A few times e) Not at all

f) If above frequency does not fit your condition:

(5) Does the goal-setting task help you with self-reflection during Week 3 – Week 4?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all f) If above frequency does not fit your condition:

(6) Does the physical activity data collected by *FitBit* help you with self-reflection during Week 3 – Week 4?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all

f) If above frequency does not fit your condition:

(7) Did you get any badges during Week 3 – Week 4? What are they? List your badges awarded by *FitBit*:

(8) How much awareness towards walking was heightened throughout the day because of the use of the Goal Setting Task during Week 3 – Week 4?

Not at all Very much

____

0 100

(9) How much awareness towards walking was heightened throughout the day because of the use of *FitBit* during Week 3 – Week 4?

Not at all Very much

____

0 100

(10) To which degree would you perceive Goal Setting Task as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

____

0 100

(11) To which degree would you perceive self-monitoring as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

____

0 100

(12) How often do you think about your physical activity during Week 3 – Week 4?

____

0 100

(13) How often do you actually DO something about your physical activity (like exercising, more walking) during Week 3 – Week 4?

0 100

(14) How would you evaluate your daily activity level during Week 3 – Week 4?

0 100

(15) Do you find yourself to be motivated to keep an active physical activity level during Week 3-Week 4?

Not at all Very much

0 100

(16) If you feel to be motivated, to which degree does it relate to the goal setting task during Week 3-Week 4?

Not at all Very much

0 100

(17) If you feel to be motivated, to which degree does it relate to self-monitoring during Week 3-Week 4?

Not at all Very much

0 100

2.2 Below questions were used in the Social Community group:

(1) How often did you have *FitBit* with you during Week 3 – Week 4? (Be honest! :)

a) Everyday b) 4-5 days/week c) 2-3 days/week d) 1 day/week e) Never

f) If above frequency does not fit your condition:

(2) How often did you check your mobile *FitBit* application during Week 3 – Week 4?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(3) How often did you check your *FitBit* website dashboard during Week 3 – Week 4?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(4) How often did you reflect upon your physical activity data based on the data from *FitBit* App/dashboard during Week 3 – Week 4?

a) Very Often b) Usually c) Sometimes d) A few times e) Not at all

f) If above frequency does not fit your condition:

(5) Does the goal-setting task help you with self-reflection during Week 3 – Week 4?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all f) If above frequency does not fit your condition:

(6) Does the physical activity data collected by *FitBit* help you with self-reflection during Week 3 – Week 4?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all

f) If above frequency does not fit your condition:

(7) Did you get any badges during Week 3 – Week 4? What are they? List your badges awarded by *FitBit*:

(8) How much awareness towards walking was heightened throughout the day because of Goal Setting Task during Week 3 – Week 4?

Not at all Very much

____

0 100

(9) How much awareness towards walking was heightened throughout the day because of the use of the *FitBit* online Activity Community Group during Week 3 – Week 4?

Not at all Very much

____

0 100

(10) How much awareness towards walking was heightened throughout the day because of *FitBit* Mobile App Challenge during Week 3 – Week 4?

Not at all Very much

____

0 100

(11) To which degree would you perceive Goal Setting Task as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

____

0 100

(12) To which degree would you perceive self-monitoring as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

____

0 100

(13) To which degree would you perceive *FitBit* online Activity Community Group as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

0 ______________________________ 100

(14) To which degree would you perceive *FitBit* Mobile App Challenge as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

0 ______________________________ 100

(15) How often do you think about your physical activity during Week 3 – Week 4?

0 ______________________________ 100

(16) How often do you actually DO something about your physical activity (like exercising, more walking) during Week 3 – Week 4?

0 ______________________________ 100

(17) How would you evaluate your daily activity level during Week 3 – Week 4?

0 ______________________________ 100

(18) Do you find yourself to be motivated to keep an active physical activity level during Week 3-Week 4?

Not at all Very much

0 ______________________________ 100

(19) If you feel to be motivated, to which degree does it relate to the goal setting task during Week 3-Week 4?

Not at all Very much

0 100

(20) If you feel to be motivated, to which degree does it relate to self-monitoring during Week 3-Week 4?

Not at all Very much

0 100

(21) If you feel to be motivated, to which degree does it relate to *FitBit* Mobile App Challenge during Week 3-Week 4?

Not at all Very much

0 100

(22) If you feel to be motivated, to which degree does it relate to *FitBit* online Activity Community Group during Week 3-Week 4?

Not at all Very much

0 100

2.3 Below questions were used in the FitPet mobile game group:

(1) How often did you play *FitPet* game during Week 3 – Week 4? (Be honest! :)

a) Everyday b) 4-5 days/week c) 2-3 days/week d) 1 day/week e) Never

f) If above frequency does not fit your condition:

(2) Does the *FitPet* Game help you with self-reflection during Week 3 – Week 4?

a) Yes, very much b) Yes, a little c) Not sure d) Never

(3) Does the goal-setting task help you with self-reflection during Week 3 – Week 4?

a) Yes, very much b) Yes, a little c) Not sure d) Never

(4) How would you evaluate the Readability of the *FitPet* Game?

Very hard to read Very easy to read

0 100

(5) How would you evaluate the Comprehension of *FitPet* Game?

Very hard to understand Very easy to understand

0 100

(6) How would you evaluate the Attractiveness of *FitPet* Game?

Not attractive at all Very attractive

0 100

(7) How would you evaluate the Emotional Engagement with *FitPet* Game?

Not at all Very much

0 100

(8) How much awareness towards walking was heightened throughout the day because of the use of *FitPet* Game during Week 3 – Week 4?

Not at all Very much

0 100

(9) How much awareness towards walking was heightened throughout the day because of the use of goal setting task during Week 3 – Week 4?

Not at all Very much

0 100

(10) To which degree would you perceive Goal Setting Task as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

0 100

(11) To which degree would you perceive *FitPet* Game as an effective approach to promote your physical activity during Week 3 – Week 4?

Very Ineffective Very effective

0 100

(12) Select the Main Features of *FitPet* Game you have experienced during the past two weeks:

Feed Food Medicine Help Mini Game Activity Logs Pet Store (buy accessories) Set Goals

(13) How often do you think about your physical activity during Week 3 – Week 4?

0 100

(14) How often do you actually DO something about your physical activity in the past two weeks (like exercising, more walking) during Week 3 – Week 4?

0 100

(15) How would you evaluate your daily activity level during Week 3 – Week 4?

0 100

(16) Do you find yourself to be motivated to keep an active physical activity during Week 3 – Week 4?

Not at all Very much

0 100

(17) If you feel to be motivated, to which degree does it relate to the *FitPet* Game during Week 3 – Week 4?

Not at all Very much

0 100

(18) If you feel to be motivated, to which degree does it relate to the Goal Setting Task during Week 3 – Week 4?

Not at all Very much

0 100

(19) Do you feel guilty or shameful when your virtual pet is sick or dying?

Not at all Very much

0 100

What is your emotion when it is sick?

(20) Do you feel satisfied or happy when your virtual pet is healthy and happy?

Not at all Very much

0 100

What is your emotion when it is healthy? :

(21) Do you like to play and interact with your virtual pet?

Not at all Very much

0 100

What are the interactions/features not there but you wish you had? :

(22) Is it hard for you to get game coins to spend on the pet out of your daily steps? What exchanging rate is more suitable for you? (It’s 30 steps to 1 coin NOW)

Not at all Very much

0 100

7. Post-intervention Questionnaire

Below questionnaire was for all three experimental groups:

(1) How often did you have *FitBit* with you during Week 5 – Week 6? (Be honest! :)

a) Everyday b) 4-5 days/week c) 2-3 days/week d) 1 day/week e) Never

f) If above frequency does not fit your condition:

(2) How often did you check your mobile *FitBit* application during Week 5 – Week 6?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(3) How often did you check your *FitBit* website dashboard during Week 5 – Week 6?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(4) (*FitPet* group ONLY) Do you still play *FitPet* Game? If yes, how often did you play *FitPet* game during Week 5 – Week 6?

a) Every 1-2 hours b) Every 3-4 hours c) 3-4 times/day d) 1-2 times/day e) Never f) If above frequency does not fit your condition:

(5) Do you still set up goals for yourself? If yes, does the goal-setting task help you with self-reflection during Week 5 – Week 6?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all f) If above frequency does not fit your condition:

(6) Did you start challenges with others? If yes, how often do you play it with others during Week 5 – Week 6?

a) More than 4 times b) 2-3 times c) Once d) Never f) If above frequency does not fit your condition:

(7) Did you check in the online social community group? If yes, how often did you check it during Week 5 – Week 6?

a) More than 4 times b) 2-3 times c) Once d) Never f) If above frequency does not fit your condition:

(8) (*FitPet* group ONLY) Does the *FitPet* game help you with self-reflection during Week 5 – Week 6?

a) Yes, very much b) Yes, a little c) Not sure d) Not at all

f) If above frequency does not fit your condition:

(9) Did you get any badges during Week 3 – Week 4? What are they? List your badges awarded by *FitBit*:

(10) How much awareness towards walking was heightened throughout the day because of Goal Setting Task during Week 5 – Week 6?

Not at all Very much

0 100

(11) How much awareness towards walking was heightened throughout the day because of the use of the *FitBit* online Activity Community Group during Week 5 – Week 6?

Not at all Very much

0 100

(12) How much awareness towards walking was heightened throughout the day because of *FitBit* Mobile App Challenge during Week 5 – Week 6?

Not at all Very much

0 100

(13) How much awareness towards walking was heightened throughout the day because of *FitPet* mobile game during Week 5 – Week 6?

Not at all Very much

0 100

(14) To which degree would you perceive Goal Setting Task as an effective approach to promote your physical activity during Week 5 – Week 6?

Very Ineffective Very effective

0 100

(15) To which degree would you perceive self-monitoring as an effective approach to promote your physical activity during Week 5 – Week 6?

Very Ineffective Very effective

0 100

(16) To which degree would you perceive *FitBit* online Activity Community Group as an effective approach to promote your physical activity during Week 5 – Week 6?

Very Ineffective Very effective

0 100

(17) To which degree would you perceive *FitBit* Mobile App Challenge as an effective approach to promote your physical activity during Week 5 – Week 6?

Very Ineffective Very effective

0 100

(18) (*FitPet* group ONLY) To which degree would you perceive *FitPet* Mobile Game as an effective approach to promote your physical activity during Week 5 – Week 6?

Very Ineffective Very effective

0 100

(19) How often do you think about your physical activity during Week 5 – Week 6?

0 100

(20) How often do you actually DO something about your physical activity (like exercising, more walking) during Week 5 – Week 6?

0 100

(21) How would you evaluate your daily activity level during Week 5 – Week 6?

0 100

(22) Do you find yourself to be motivated to keep an active physical activity level during Week 5 – Week 6?

Not at all Very much

0 100

(23) If you feel to be motivated, to which degree does it relate to the goal setting task during Week 5 – Week 6?

Not at all Very much

0 100

(24) If you feel to be motivated, to which degree does it relate to self-monitoring during Week 5 –Week 6?

Not at all Very much

0 100

(25) If you feel to be motivated, to which degree does it relate to *FitBit* Mobile App Challenge during Week 5 – Week 6?

Not at all Very much

____

0 100

(26) If you feel to be motivated, to which degree does it relate to *FitBit* online Activity Community Group during Week 5 – Week 6?

Not at all Very much

____

0 100

(27) (*FitPet* group ONLY) If you feel to be motivated, to which degree does it relate to *FitPet* mobile game during Week 5 – Week 6?

Not at all Very much

____

0 100