HAMKERUN: MOBILE INFOVIS APP TOWARDS SUSTAINABLE MOTIVATION IN A CONTEXT OF RUNNING

Sung Pil Moon

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Doctor of Philosophy
in the School of Informatics and Computing,
Indiana University

May 2015

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Doctoral Committee

Davide Bolchini, Ph.D., Chair

Mark Pfaff, Ph.D.

Kevin Rand, Ph.D.

Stephen Voida, Ph.D.

August 4, 2014

DEDICATION

To all caregivers

ACKNOWLEDGMENTS

This dissertation indicates the end of my long journey in obtaining my PhD degree. It is my great pleasure at this point to express my appreciation to those who have contributed to completing my dissertation. I would never have been able to finish without the guidance of my committee members, helps and support from my family and friends.

First and foremost, I would like to express special appreciation and deepest gratitude to my advisor, Dr. Mark Pfaff who has been more than an academic advisor and supporter for me for doing my research. He dedicated much of his time and energy in providing excellent and thoughtful guidance, caring, and patience whenever I encountered difficulties.

I would also like to enormously thank my dissertation committee members, Dr. Davide Bolchini, Dr. Stephen Voida, and Dr. Kevin Rand, for their brilliant expertise, guidance and contributions to my dissertation. It has been a fantastic experience working with them and I always feel motivated to focus on my work and enabled me to continuously improve the quality of my dissertation. Their guidance has been extremely helpful, invaluable and greatly appreciated.

I also owe many thanks to my current and previous colleagues in the Grappa lab and the USER lab, who offered flashy feedback and suggestions on this dissertation. Special thanks to Yang Tao who were accepted to the HCI PhD together and has always provided me kind and insightful guidance on my dissertation writing with his strong statistical analysis skills. I would also like to thank Powit Rungsangthiwakorn who has

given his time and effort to help developing the backend-side of the HamkeRun application. I wish all of you best of luck in your research, careers, and future.

I would like to acknowledge and thank the financial, academic and technical support by faculty members and staffs in the School of Informatics and Computing, Indiana University. I really appreciate that all of you have always been there to support me whenever I needed help. Another appreciation should be directed to the participants who shared their experiences and insights while they use the HamkeRun mobile application.

Special and sincere thanks go out to Father Jaehyun Choi, friends and families in the Indianapolis Korean Catholic Church. Father Choi has been served as my mentor and has taught me a lot about life and how to handle difficult situations. I also would like to give my thanks to the families who have provided kind and thoughtful considerations of me. My six years journey of PhD life would not have been wonderful without them. The times that I shared with them and all of the interesting conversations will always be memorable to me.

The last but not least, I would like to appreciate the constant and unlimited support and prays from my family, Won Suk Moon, Keum Lye Koh, Jae Hee Moon, and Sung Min Moon. There aren't enough words to describe how grateful I am. Great thank you for supporting me for everything.

Sung Pil Moon

HAMKERUN: MOBILE INFOVIS APP TOWARDS SUSTAINABLE MOTIVATION IN A CONTEXT OF RUNNING

According to the US Centers for Disease Control and Prevention, less than half of all adults in the US meet basic physical activity guidelines. Physical activity can help not just improve physical and mental health but also reduce the risk of heart disease and some cancers. Researchers and companies have tried to investigate the use of modern technologies to motivate people to increase and maintain physical activities. However, in spite of these efforts, there are criticisms. Those include low dietary effectiveness of the tools, lack of sustainable effects in the long-term, and proof of effectiveness only shown in laboratory settings.

To overcome these limitations, first, the author developed a framework of overarching motivation theories and HCI factors and contextualized it within the running domain. Second, the author has developed a mobile application called HamkeRun within this framework, using the concepts of information visualization, gamification, and social grouping to increase a user's motivation to run more frequently. Third, the HamkeRun application was empirically tested through a two-month-long longitudinal experiment and follow-up interviews. The results showed that the single runner type showed significant increases in the levels of their external motivation (motivational effect of the HamkeRun application), internal motivation and satisfaction, while the team runner type showed significant increases only in internal motivation. In addition, motivational effects were

also different depending on the runners' behavior change stage. Runners at the maintenance stage showed significant increases in external motivation, internal motivation, satisfaction, and total number of running activities performed during the study. Although action stage runners showed significant increase in internal motivation, female runners at the action stage showed significant decrease in their external motivation. Gamification greatly influenced increases of external motivation, internal motivation and total number of actual activities. Although both male and female runners showed increased internal motivation, significant increase in external motivation was only found in male runners. The dissertation closes with a series of design guidelines for application developers and designers which may help develop motivational tools in other health-related domains.

Davide Bolchini, Ph.D., Chair

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

According to the US Center for Disease Control and Prevention (2008), less than half (48%) of all adults in the US meet the physical activity guidelines as less than 5% of the adults in the US participate in physical activity for 30 minutes each day and only one-third of US adults meet the recommended amount of physical activity each week (President's Council on Fitness, Sports & Nutrition, 2010). Globally, one-third of adults and four out of five adolescents do not complete enough aerobic physical activity to meet the public healthiness on the recommended levels of physical activity (Hallal, Andersen, Guthold, Haskell, & Ekelund, 2012).

The reasons for these trends are partly due to insufficient participation in physical activity during leisure time, more sedentary lifestyles, eating patterns and environmental and social factors. Also, developments in motorized transportation and increased urbanization are examples of other factors (Biddle et al., 2004; Lutfiyya et al., 2008). A recent report from the World Health Organization (2014) showed that approximately 3.2 million people die each year worldwide because of insufficient levels of physical activity, and physical inactivity causes noncommunicable diseases (NCDs), such as cardiovascular diseases, cancer and diabetes.

Physical activity can help not just improve physical and mental health, but also reduce the risk of heart disease and some cancers. Namely, appropriate levels of physical activity regularly result in, for example, strengthened muscular and cardiorespiratory fitness; improved bone and functional health; reduced risk of heart disease, stroke, diabetes and breast cancer; energy balance; and weight control.

Researchers and companies have tried to investigate the use of modern technologies to motivate people to increase and maintain physical activities. These technologies vary in types and purposes. For example, Houston (Consolvo, Everitt, Smith, & Landay, 2006) is a prototype mobile application designed to encourage physical activity by sharing step counts with friends, while Shakra (Barkhuus, 2007) is a mobile activity tracker for adolescents to induce physical activity by exchanging physical activity information with their friends. The Nuadu toolbox is a set of applications for personal health management (Mattila et al., 2008) that provides assessment and performance of users' physical activities. The results of the empirical studies on these tools showed that the participants were significantly more likely to meet their goals of increasing their frequency of physical activities and effectiveness (Consolvo et al., 2006; Barkhuus, 2007; Aino et al., 2009).

Many Active Video Games (AVGs), such as Dance Dance Revolution (DDR), Nintendo Wii Fit games and Microsoft Kinect games, have been developed by leveraging the advantages of video games, such as enjoyment, sustained attention and interactions with players. There have been efforts to apply these AVGs to encourage physical activity in children and youth, while decreasing sedentary activity (Graf et al., 2009; Hands, Larkin, Parker, Straker, & Perry, 2009; Leatherdale et al., 2009; Murphy et al., 2009; Foley et al., 2010; Biddiss & Irwin, 2010). Several studies on the effectiveness of AVGs have demonstrated that energy expenditure was significantly higher during AVG play when compared to inactive gaming or being at rest (Leatherdal, Woodruff, & Manske, 2010; Graf et al., 2009; Lanningham-Foster et al., 2009).

However, in spite of these efforts, criticisms exist, including a lack of sustainable effects in the long-term, the low dietary effectiveness of the tools and that the proof of effectiveness is only shown in laboratory settings. Although the participants in the experiments with Houston and Shakra provided positive feedback and showed effectiveness of the tools, the durations of those experiments - around two weeks - were too short to show longer and sustainable effects of the tools on changes in the participants' behaviors. In addition, no empirical evidence exists to identify the factors enticing the participants regularly participate in physical activity. Moreover, the frequency of AVG play and its efficacy in the long-term remain unknown in spite of its effectiveness of energy expenditure in the short-term (Biddis & Irwin, 2010).

Additional criticism exist regarding the dietary effectiveness of playing video games to increase physical activity due to low energy expenditure of the activity. Although the energy expended during game playing was significant higher than when playing sedentary video games or staying sedentary, it did not reach the recommended daily amount of calories required for children to lose weight (Graves et al., 2007). Debates have also occurred about the relationship between sedentary and physical behaviors. On the one hand, several researchers have argued that sedentary behaviors, such as TV viewing and playing video games, are influential determinants for juvenile physical inactivity and obesity (Falciglia & Gussow, 1980; Gortmaker et al., 1996; Steinbeck, 2001). They have also argued that decreasing sedentary behavior, while increasing physical activity is an important factor to treating youth obesity (Epstein et al., 1995). On the other hand, some researchers have argued that sedentary behaviors are not largely correlated with physical activity, suggesting that youth have time for both

sedentary and physical behaviors. No significant differences exist in regard to the time spent on sedentary activity compared to children 40 years ago (Biddle et al., 2004). Several longitudinal studies also failed to demonstrate a significant relationship between low energy expenditure and youth obesity as well as physical inactivity (Ekelund et al., 2002; Ogden, Flegal, Carrol, & Johnson, 2002; Salbe et al., 2002).

Therefore, the central directions of this dissertation are to overcome these limitations and increase motivation to perform physical activities, especially running activities, by utilizing persuasive elements in a mobile application. The use of a mobile phone is based on the idea that mobile phones are one of the major persuasion platforms used today due to the ubiquitous nature of the phone and that fact that phone are almost always with their users (Fogg & Eckles, 2007). For instance, mobile phones were used in an experiment aimed at changing participants' sedentary lifestyles to more active lifestyles by persuading them to regularly participate in physical activities. Also, in a running context, it does not require users to input activity data too frequently, compared to other physical activities, such as exercise, and several ways exist to wear and carry mobile phones while running, including in an armband or on an item belt. Therefore, it is easy to keep track of runners' activity data and for the application to maintain persuasive power during the activity.

This study employed a two-month longitudinal experiment with 30 participants who are runners at different stages of behavior change. I designed and developed a persuasive mobile application, called HamkeRun, which embedded the concepts of information visualization, gamification and social elements. These three concepts were selectively chosen from intensive literature reviews to provide effective persuasive power.

Then, the study empirically tested the effects of these persuasive motivational elements to see whether they resulted in increased motivation on the part of the runners and an increased amount of running activities. The theoretical framework was iteratively refined and verified based on the results of the study and the literature reviews.

The results of the study demonstrated that the HamkeRun application provided strong positive persuasive effects on internal motivation, which is the internal momentum for achieving a target behavior, and provided moderately positive levels of external motivation, which is the overall motivational effect of the persuasive elements in the application, while it showed selectively positive effects on satisfaction and the total number of running activities depending on runner type, stage of behavior change, gamification and gender. These results have implications that (1) persuasive motivational elements should be elaborately and deliberately tailored and provided differently to runners at different stages of behavior change and (2) a gap exists between the motivation domain and the actual behavior domain. Therefore, more effective and powerful triggers at the right moment should be provided.

The contributions of the dissertation include (1) the theoretical framework in the context of running that combines two separate theoretical models: the transtheoretical model of behavior change (TTM; Prochaska, & DiClemente, 1983; Prochaska & Marcus, 1984) and Fogg's Behavior Model (FBM; Fogg, 2009). This theoretical framework was used to explain the cognitive and motivational models of the runners in each stage of behavior change when they received persuasive motivational elements from the HamkeRun application; (2) the development of a persuasive mobile application that employs a set of persuasive technologies and the concepts of information visualization,

gamification and social elements; (3) empirical test results of the effectiveness of these concepts within the context of running; and (4) design guidelines for persuasive application developers and designers, not just in physical activity domains, but also in health-related fields where persuasion and behavior change have significant impact.

The rest of the chapters in this dissertation are organized as follows. Chapter 2 presents an extensive literature review on the theories of motivation, behavior change and persuasive technologies. Chapter 3 describes the process of developing the HamkeRun application and the procedures of the experiment that empirically tested the effectiveness of the persuasive motivation elements provided in the application. Chapter 4 summarizes the results of the data analysis from the experiment. Chapter 5 discusses the theoretical framework revisited, the findings obtained from the experimental results and follow-up interviews, and the design guidelines for persuasive designers and developers. Chapter 6 summarizes the contributions of this dissertation, its limitations and possible future research directions.

CHAPTER 2: BACKGROUND

In this chapter, the research undertaken to examine for the core concepts of motivation, behavioral change and persuasive technologies are discussed. This includes historical and recent literature on the constructs of motivation and behavior change as well as persuasive technologies. The timeline of the literature researched ranges from the 1940s to the present day. In the first section of the literature review, 'Motivation,' classical theories and models are presented in order to explain the construct of motivation from a psychological perspective. These include Maslow's hierarchy of needs theory, the ERG theory, McClelland's need theory, reinforcement theory, expectancy theory and goal-setting theory. For the second section, 'Behavior change,' the literature focuses on explaining and linking the construct of motivation to actual behavioral changes. This second section covers the theories of reasoned action / planned behaviors, transtheoretical theory and Fogg's behavior model. The third section discusses persuasive technologies with persuasive strategies and design principles to make systems for behavior change more persuasive. This section also provides several state-of-the-art examples on how the theories and models in the previous sections have been applied to arouse, change and maintain motivations and behaviors. The exemplar persuasive technologies are presented in the domains of marketing, safety, environmental consumption and health, where persuasive technologies have significant potential and impacts.

2.1. Motivation

Motivation plays a significant role in how people conduct behaviors and complete tasks toward goals in various areas, such as work, physical activities, exercise and sports. As the construct of motivation is considered to be an important determinant for commitment and a driving force to take actions aimed at achieving goals, it has been widely investigated (Iso-Ahola & St. Clair, 2000; Murcia, Galindo, & Pardo, 2008). Many researchers have tried to explain the construct of motivation and various theories have been proposed.

2.1.1. Maslow's Hierarchy of Needs Theory

Most of the theories that investigate the construct of motivation are rooted in the hierarchy of needs (Maslow, 1943) due to its simplicity, rationality and applicability to behavior (Porat, 1977). The hierarchy of needs theory identifies a hierarchical set of five basic needs: physiological need, need for security, need for belongingness and love, need for esteem, and need for self-actualization. Physiological need is the need at the lowest level to achieve basic physical comfort or bodily needs, such as food, sleep, sex and drink water. The need for security is the need to feel safe, secure and free from fear. The need for belongingness and love is the need to feel affection, intimacy and social acceptance from friends and family. The need for esteem is the need to be regarded as useful, competent and important. The need for self-actualization is the need to actualize one's full potential to become what one really wants to be. This level is the highest motivation level. The hierarchy of needs is often displayed as a pyramid (Figure 1). The basic needs

are located in the lower levels of the pyramid, while the more complex needs are located in the higher levels.

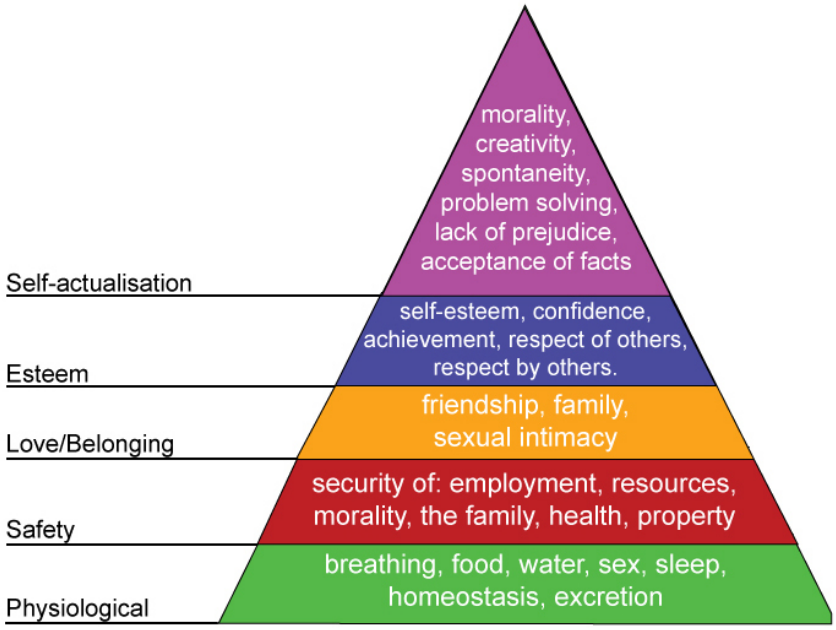

Figure 1. Maslow's hierarchy of needs. Retrieved from http://ideasuk.files.wordpress.com/

Maslow viewed human needs in as either needs of a deficiency or a growth. On the one hand, the deficiency needs occur when the needs are not fulfilled. Such a deficiency serves as a strong motivator to take a behavioral action to achieve the necessary needs in order to avoid unpleasant feelings or negative consequences. For example, if people have been left without food for a long time, they will try to find food instead of starving or taking other irrelevant actions. The longer the deficiency needs are not fulfilled, the stronger the motivator to achieve the needs will be. The deficiency needs include physiological, security, belongingness and love, and esteem needs. An important property of the deficiency need is that when one deficiency need is satisfied, another desire at a higher level will take its place. Namely, when one set of needs is satisfied, then the needs at the current level will cease to be a motivator, while the needs at the next

level will become a strong motivator. The deficiency needs are especially stronger at the lower levels. On the other hand, a growth need is based on the fact that people are not simply biological beings and, as such, they want to grow and develop as people and seek to achieve their individual potentials. Growth needs are different from deficiency needs in that they do not occur due to a deprivation of something, but, rather, a desire to grow as an ideal self.

However, in spite of the popularity of the hierarchy of needs theory, it has been criticized due to its limitations. The first limitation is a lack of scientific evidence for the theory (Wahba & Bridwell, 1976; Rauschenberger, Schmitt, & Hunter, 1980; Hofstede, 1984; Soper, Milford, & Rosenthal, 1995), since the theory was based more on clinical insights instead of being developing under appropriate and rigorous scientific research. The definitions of the needs are vague and the needs are difficult to measure statistically and empirically (Wahba & Bridwell, 1976). Due to this weakness of validity, the hierarchical rankings of the needs and its order are also often criticized. Moreover, another criticism focuses on the coexistence of different needs at different levels, meaning that a particular need does not simply disappear although one need is fulfilled (Hall & Nougian, 1968, as cited in Gibson & Teasley, 1973; McLeod, 2007; Kenrick, 2010). Namely, needs at different levels can coexist and the highest rank, self-actualization, can be fulfilled without meeting all of the lower needs.

Finally, Maslow's hierarchy of needs lacks consideration of sociological context (Nevis, 1982; Raymond, Mittelstaedt, & Hopkins, 2003; Tay & Diener, 2011). As the theory was developed in the US, an individualist culture containing only Americans, it is not applicable to different cultures where people frequently value needs differently. For

example, some people still highly value the need for self-actualization, although their basic needs are not fulfilled. Chinese people in the 1980s showed a pattern of having belongingness being the lowest level, while the self-esteem need was eliminated. Similarly, blue-collar workers in Korea showed the pattern in ascending order of belongingness, esteem, physiological (need), safety and self-actualization, respectively (Raymond, Mittelstaedt, & Hopkins, 2003).

2.1.2. ERG Theory

Alderfer (1969) proposed the ERG theory of a motivation to expand and attempt to remedy some limitations of Maslow's hierarchy of needs theory by allowing more flexible movements of the needs. The ERG theory is composed of three needs: **E**xistence need, **R**elatedness need and **G**rowth need. The first component is the existence need, which focuses on being physically well. The second need is the relatedness need and focuses on having satisfactory relationships with others, while the third need is the growth need, which focuses on personal growth and increased competence by developing one's own potential. The similarities between the ERG theory and Maslow's theory are that the ERG model is also hierarchical, covers similar needs and combines overlapping constructs (i.e., needs). For example, the existence needs correspond to the physiological and safety needs, the relatedness needs cover the social and external esteem needs, and the growth needs cover the self-actualization and internal esteem needs.

Several differences exist between the ERG theory and Maslow's theory. First, in the ERG theory, the different levels of needs can be pursued simultaneously without any specific order and the order of the needs vary for different people. The ERG theory

acknowledges that people can regress to lower level needs that are easier to satisfy if they cannot pursue a higher level need. This regression usually results in frustration, which is called frustration-regression. However, exceptions to frustration-regression exist. The first exception is when an existence need is not met, thus one will develop a strong motivation to achieve the existence needs. For example, if an individual has been left without food for a long time, he or she would develop a greater existence need, namely, trying to find food first instead of taking other actions or starving. The second exception is in the growth need where a greater need of growth occurs when the current growth need is fulfilled. Namely, when an individual achieves success in business, he or she will have a still greater need to achieve greater success. Although the biggest strength of the ERG theory is its flexibility, it is also a weakness (Rauschenberger, Schmitt, & Hunter, 1980). It is difficult not only to measure what motivates people to behave a certain way, but also to determine what is their most important need.

2.1.3. McClelland's Acquired Need Theory

McClelland's acquired need theory (or need theory; McClelland, 1965) is the motivational model that describes how an individual's needs are shaped in one's life experiences over time and how those experiences affect one's behaviors. Three major motivators (or needs) exist in the need theory: need for achievement, need for affiliation and need for power. People with the need for achievement seek to obtain accomplishments, mastering of skills and the attainment of realistic, but challenging goals. They prefer to take calculated risks to accomplish their goals and receive regular feedback on their progress. People with the need for affiliation want to belong to a group.

They prefer to create and maintain social relationships with others. They also favor collaboration over competition because they do not like high risks or uncertainty. People with the need for power want to control and influence others. They want to win arguments and prefer competition and winning. They possess motivation and the need to increase personal status and recognition. McClelland stated that all people have these three motivators to different degrees and have different characteristics depending upon their dominant motivators in spite of their ages, genders, races or cultures. In addition, unlike in the previous theories, needs are not innate in individuals, but can be learned and developed. Therefore, the acquired need theory showed a higher predictability than Maslow's hierarchy of needs theory and the ERG theory in some circumstances where people are motivated to seek out and perform well in jobs that match their needs. Another strength is that much more empirical evidence exists to support the theory than Maslow's theory or the ERG theory (Redmond, 2010).

In spite of these advantages, one of the limitations is the applicability of the theory due to cultural factors. Namely, different cultures often value different needs. For example, some cultures consider a failure as a learning experience for the next step, while other cultures view it as just a lack of success. Also, critics of the need theory have pointed out a relative lack of predictive power, especially related to entrepreneurship; that is, no direct correlation exists between one's decision to own or manage a business and the need for achievement because many other factors exist that drive people to become entrepreneurs (Smith-Hunter, Kapp, & Yonkers, 2003)

2.1.4. Reinforcement Theory

The reinforcement theory (Skinner, 1974) is a popular theory that tries to explain the relationship between motivation and behaviors. It has been widely used in such as areas as motivating employees in workspaces, animal training and raising children. The theory proposes that the behaviors of an individual are shaped and learned by the consequences of their behaviors. Namely, people would be more likely to perform specific behaviors if pleasurable rewards followed, while they would be less likely to perform the behaviors if negative consequences followed, such as punishment or the removal of pleasure. People learn the relationship between positive and negative consequences and their behaviors and then repeat or avoid the behaviors. The reinforcement theory focuses more on observable behaviors and environmental factors than on the inner state of an individual. The environmental factors that shape the behavior are called stimuli. There are four primary approaches to the reinforcement theory: positive reinforcement, negative reinforcement, positive punishment and negative punishment.

Positive reinforcement is based on the observation that pleasant or desirable consequences are the main causes of an individual's behaviors to be performed and repeated. Namely, when positive reinforcement is used, the frequency of the behaviors that an individual will perform and repeat will be increased. Positive reinforcement frequently uses the reward system, which is a collection of brain structures attempting to control behaviors with pleasurable effects (Redmond, 2010). Some examples of the reward system include verbal praise, monetary bonuses and promotions. Skinner explained the effect of positive reinforcement in experiments on rats (McLeod, 2007, as

cited in Redmond, 2010). In the experiment, a hungry rat was placed in a box that contained a specially designed lever inside that would provide food if hit. Through several trials and errors, the rat learned the relationship between hitting the lever and the food provision.

Negative reinforcement is based on the observation that desired responses result from the removal of an unpleasant stimulus. An individual will perform or repeat behaviors when something unpleasant to him or her is removed. For instance, alleviation of a strict evaluation system or monitoring system on employees will likely lead to higher performance. In Skinner's experiments on rats, he proved the effects of negative reinforcement. An electric current was placed inside the box where a lever could be used to turn it on or off. Through several trials and errors, the rat was able to learn that hitting the lever resulted in turning off the electric current inside the box.

Table 1. A classification of reinforcement and punishment

	Pleasant Stimulus	**Unpleasant Stimulus**
Presence	Positive Reinforcement	Positive Punishment
Absence	Negative Reinforcement	Negative Punishment

Punishment, as the name implies, involves reducing or suppressing behaviors. There are two types of punishment: positive and negative. Positive punishment involves presenting an unpleasant or aversive stimulus to an individual who performed a certain behavior in order to decrease the possibility of his or her performing it again. For instance, when a school gives punishment to a student who cheated on an exam, the

cheating behavior will be less likely to occur again. Although positive punishment is considered to be effective in reducing or suppressing undesired behaviors, it has several limitations (Skinner, 1974, as cited in Pierce & Cheney, 2013). It is less effective when there is a delay between presenting the positive punishment and the undesired behavior. It is also less effective when positive punishment is not consistently provided after the undesired behaviors occur. Positive punishment may produce undesirable emotional reactions, such as antagonism, hostility, fear, antipathy and blaming oneself. The biggest limitation is that it is almost impossible to teach desirable behaviors.

Negative punishment removes or gradually weakens pleasant stimulus from an individual, which leads to a decrease in the possibility that the individual will perform the behavior again. When a pleasing stimulus that causes the undesirable behavior is reduced or removed, the individual will be less likely to perform the behavior again. For instance, when a mother less often responds to her young child's begging by giving him a toy, the frequency of his begging will decrease. Extinction occurs when performing a certain behavior will not produce any consequences, thus gradually leading to a cessation of the behavior. In Skinner's box experiment, a rat ceased the behavior of hitting the lever that provided the food when it eventually learned that the behavior would no longer produce food. There are limitations of extinction. Undesirable behaviors may return when the extinction process is complete. This is called spontaneous recovery (Coon, 2006, as cited in Redmond, 2010). Additionally, desired behaviors may be eliminated unintentionally when negative punishment is provided and good behavior is consistently ignored (Tosi, Mero, & Rizzo, 2000, as cited in Redmond, 2010). In order to maintain its effectiveness,

Booth-Butterfield (1996) provided four guidelines that state that the punishment should be immediate, intense, unavoidable and consistent.

The reinforcement theory has several advantages and disadvantages (Redmond, 2010). A large amount of research has been centered on the reinforcement theory because of its focus on observable behaviors, which can be empirically proven. Next, the theory is easier to use to motivate people and easier to apply practically in real-world settings. The main reason for is because the reinforcement theory focuses on external and environmental factors, unlike the needs theory of motivation, which focuses on the internal needs of an individual. For instance, within the workplace, providing external factors, such as promotions or pay increases, may be easier and more effective than changing employees' motivations to produce higher performances.

Focusing heavily on external factors, while ignoring the processes of internal motivation or individual differences is one of the weaknesses of the reinforcement theory (Funder, 2010, as cited in Redmond, 2010). Partially due to this reason, it is also difficult to apply this theory to complicated forms of behaviors resulting from both internal and external factors. Furthermore, it can be difficult to identify the main causes of behavioral change behind rewards or punishments (Booth- Butterfield, 1996; as cited in Redmond, 2010). That is to say, since each individual has different and unique characteristics, the rewards or punishments that work for some people may not work for others. Next, albeit successfully leading to having the desired behaviors performed, the effectiveness of the reinforcement theory may often expire. When reinforcement or punishment is provided repeatedly over time, its effectiveness becomes lower than after the initial use. An individual who has received reinforcement or punishment may experience fatigue.

Therefore, it is important to carefully use artificial reinforcers because they often result in reducing an individual's feeling of self-determination, which may be more likely to decrease an individual's motivation to perform similar behaviors in the future (Glasser, 1990, as cited in Redmond, 2010).

2.1.5. Expectancy Theory

The expectancy theory is a model that more directly explains the concept of motivation than the above theories (Vroom, 1964). This theory states that individuals will perform an action at a particular level of effort to reach a goal if they think that the goal is worth achieving (valence) and if their assessment of the probability that their effort will lead to the expected outcomes (expectancy) is positive. Restated, the theory attempts to explain the behavioral directions as to why an individual chooses one behavioral option among alternatives. The expectancy theory is based on three components: expectancy, valence and instrumentality. Expectancy is a subjective momentary belief about the probability that desired outcomes will be obtained if particular actions are taken. For example, one can expect possible productivity if he or she works harder within a limited timeframe. The expectancy is based on a combination of the individual's perceived difficulty of the goal, past experience and self-confidence. Valence is an individual's belief or emotional orientation toward the desired outcomes (rewards). Each person places different values on the desired outcome. For example, some people may not be interested in the expected reward if they need to put in extra effort. Instrumentality is a subjective belief that a reward will be obtained once the performance expectation is met. In other words, it is an individual's perception of a relationship between performance and

the outcomes. For example, one individual who worked more than others could expect that he or she would get an extra bonus. These three components combine to determine the motivations associated with an action in order to obtain expected pleasure, while avoiding pain. Vroom (1964) held that the motivation of an individual to perform an action is the product of expectancies, instrumentality and valence (Expectancy × Instrumentality × Valence).

One advantage of the expectancy theory is that it can explain people's behaviors in regard to getting maximum satisfaction and minimizing dissatisfaction. It can also help people choose an action among alternatives in a manner that optimizes their expected valence. Namely, for each action, people multiply their perceived valences of all possible outcomes by their expectancy of occurrence, then find the algebraic sum across all outcomes, and finally choose the action with the highest expected summation (Ferris, 1977). In addition, this theory not only focuses on an individual's internal factors, such as expectations, perceptions and psychological extravagance, but also emphasizes external factors, such as rewards.

The expectancy theory has limitations, including that the model is episodic and has difficulty explaining behaviors over time (Steel, P., 2006; Kanfer, 1990). Furthermore, in organizational settings, the theory fails to show that rewards are directly correlated with performances because performances are sometimes related to other parameters, such as position, efforts, responsibility and education (Redmond, 2010).

2.1.6. Goal-setting Theory

The goal-setting theory (Locke, 1990) is a popular motivational model that assumes that an individual's conscious goals lead to higher task performance. In the theory, a goal is defined as the object or aim of an action or task that an individual consciously desires to achieve. Unless goals conflict or an individual does not possess the proper ability, having a specific and conscious goal results in a desired performance. A challenging goal also leads to a higher task performance than vague and abstract goals (Locke & Latham, 2002). Goals are related to self-satisfaction with one's performance. One's satisfaction would be increased if the goal were considered achieved successfully or close to success. Conversely, one's dissatisfaction would be increased if one's performance did not meet the goal. The more goal successes and higher performances an individual experiences, the higher level of satisfaction he or she would achieve. Locke (1990) classified four mechanisms of the relationship between goals and performances as mediators that affect goals and, in turn, affect performance. First, goals direct people. Goals guide an individual's attention, efforts and action toward goal-relevant activities and away from goal-irrelevant activities. Second, goals energize individuals. High goals make an individual put forth greater effort, both physically and cognitively, than low goals. Third, goals affect persistence. High goals require a longer time to accomplish. When faced with difficult goals, people can choose to work slowly for a longer time or work faster and more intensely for a short time. However, when a limited time exists for a task, it leads an individual putting forth persistent effort to work intensely, such as tasks under a tight deadline. Fourth, goals motivate people to use their knowledge and skills to accomplish tasks. If an individual wants to achieve his or her goals, he or she would seek

out different and effective ways to achieve it through utilizing one's existing or new task-relevant knowledge, skills and strategies.

Four necessary conditions exist that make goals effective in regard to invoking motivation: goal acceptance and commitment, goal specificity, goal difficulty, and feedback on progress toward the goal. First, goal acceptance and commitment are that one should accept the goal as the first step in creating motivation and should commit to the goal to accomplish it. Locke (1990) stated that when people are committed to their goals, it shows a strong relationship between the goal and positive performance. When goals are difficult to achieve, goal commitment is the most important and relevant element (Klein, Wesson, & Hollenbeck, 1999) to success. Two primary sub-components exist that help improve goal commitment: importance and self-efficacy (Locke & Latham, 2002; Locke & Latham, 2006). Importance refers to whether one considers the goal as important to achieve, while self-efficacy refers to one's belief that he or she can achieve the goal. When an individual considers that his or her goal is important and believes that he or she is able to achieve it, then goal commitment is enhanced. Goal specificity refers to the idea that a goal should be specific and clear. When a goal is clear and specific, it is unambiguous and there is less misunderstanding, thus an individual will be able to estimate what behavior will follow, what current progress will be and what the expected outcomes will be. When a goal is vague, it often leads to little effect on motivation and performance. Conversely, the more specific the goal, the higher the task performance will be. However, as Locke stated (2006), goal specificity itself does not guarantee high performance, since specific goals vary in difficulty. Namely, depending upon individual differences in ability and intellect, the performance toward goals varies.

However, goal specificity reduces this variation in performance by reducing ambiguity if the performance is fully controllable (Locke, Chah, Harrison, & Lustgarten, 1989). The third condition is the goal difficulty, which is a good motivation moderator. If a moderately high goal is set, then one is most likely to achieve the goal with high performance. However, if the goal is set too high (too difficult) or too low (too easy), one would have trouble creating motivation, commitment and performance. The last condition is feedback, which makes an individual understand his current progress, while being in the course of achieving the goal. If one could not recognize his or her progress, then it would be difficult to adjust one's effort, direction or strategy toward achieving the goal.

Although the goal-setting theory has been widely accepted due to its simplicity and the large amount of empirical research on the topic (Locke & Latham, 2002), limitations do exist. First, goal conflict occurs when two or more goals are set at the same time (Latham, 2004). In an organizational setting, the goals of an individual and the goals of a manager sometimes differ. In this case, goal conflict results in a detrimental effect on performance unless the goals are aligned. Prioritizing separate goals or finding a balance between the goals can also resolve the goal conflict. The second limitation is goals and risk. This limitation occurs when an individual, who suffers from achieving a goal or has a difficult performance goal, begins to consider risk strategies to improve performance (Knight, Durham, & Locke, 2001). However, higher risk strategies likely result in low performance and negative consequences. The third limitation is personality. If an individual does not possess enough self-efficacy, meaning that he or she does not have the expertise, skills and competencies to perform the actions required to achieve the goal,

then goal-setting will fail, leading to performance detriment. The last limitation focuses on goals and subconscious motivation (Locke & Latham, 1979). The theory does not explain the actions motivated by an individual's subconscious, rather it relies more on cognitive motivations. People sometimes take actions although they don't recognize what motivates them or what stored knowledge guides them to behave in a particular way. Therefore, the goal-setting theory is more suitable to explaining individuals who have purposeful motivation.

2.1.7. Self-Efficacy and Social Cognitive Theory

The self-efficacy theory (Bandura, 1977) is also a popular theory that investigates the construct of motivation. It is a part of the social learning theory (Ashford & LeCroy, 2010, as cited in Redmond, 2010), which has progressed into the social cognitive theory (Levin, Culkin, & Perrotto, 2001, as cited in Redmond, 2010). According to Bandura (1977), self-efficacy is defined as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations." It is a judgment that an individual makes about his or her capabilities to perform particular tasks in a certain situation. Strong self-efficacy increases the likelihood of increasing an individual's effort and persistence toward tasks (Barling & Beattie, 1983, as cited in Axtell & Parker, 2003). Therefore, people with high self-efficacy tend to view problems as challenges to be resolved, would like to face the problems willingly, form a deeper commitment to the activities, develop their skills and knowledge, and recover quickly from failures or disappointments. On the contrary, people with low self-efficacy show a tendency to avoid challenges, view the problems as challenges that they cannot overcome, focus more on

negative consequences, and lose their confidence quickly in their skills and abilities. Self-efficacy is formed in early childhood and continues to develop as people acquire new skills, knowledge and experiences in a wide variety of tasks and situations.

Bandura (1977) outlined four sources that people can used to develop self-efficacy: mastery experience (performance accomplishments), vicarious experiences (social modeling), verbal persuasion (social persuasion) and physiological feedback (emotional experience). The mastery experience (or performance accomplishment) is the most important source and the most effective way to develop self-efficacy. Self-efficacy gets stronger whenever an individual performs a task successfully. Once an individual performs the task well, he or she has high self-efficacy and is more likely to be competent and perform well again at similar tasks. However, failures at tasks may cause low self-efficacy and may lead to repeated failures. Vicarious experience (social modeling) explains that that self-efficacy gets stronger when an individual sees others accomplishing tasks successfully and compares his or her own competence with others' competence. The effect will be greater when seeing similar people completing tasks. For example, a person with diabetes who is asked to engage in more physical activities by a doctor can be encouraged by stories of other individuals with diabetes who successfully completed the required tasks. However, seeing others' failures leads to reduced self-efficacy. Verbal persuasion (social persuasion) is the idea that an individual can be persuaded by others' verbal encouragement that he or she has enough capacity to accomplish tasks. Verbal persuasion leads to strengthened self-efficacy, weakened self-doubt, a belief in one's capabilities, more effort exerted and, thus, better task completion. The opposite is also true. For instance, when a soccer team manager provides negative

verbal persuasion before a match against a stronger team, the players might be negatively influenced and not demonstrate their capabilities to the fullest (or even their usual levels of abilities). Although verbal persuasion is considered a weaker source of self-efficacy belief than performance outcome, it is widely utilized because it can be used at any time without any additional effort (Redmond, 2010). Physiological feedback (emotional experience) is the least important source and affects self-efficacy of an individual through the physiological state. An individual's mental, physical and emotional states, tension and stress, and mood all influence the belief of self-efficacy – how he or she feels about their capabilities in a particular situation. As Bandura (1977) illustrated, a person may become nervous and have low self-efficacy when he or she gives a speech in front of a large number of people. However, if that person is familiar with how to minimize stress or stabilize his mental and emotional states in unfamiliar situations, he may be able to improve his self-efficacy regardless of challenging or difficult tasks.

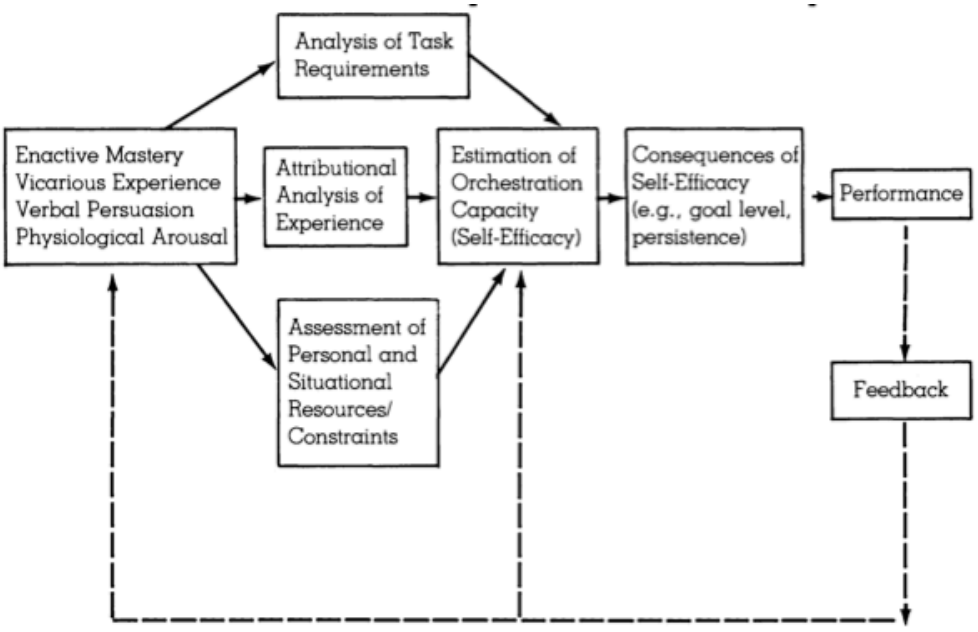

Figure 2. The model of self-efficacy-performance relationship (adapted from Gist & Mitchell, 1992)

Gist and Mitchell (1992) proposed a model of a relationship between self-efficacy and performance outcomes. It assumes that people directly or indirectly evaluate their experiences and judge the degree of their capabilities as to whether they are able to accomplish a specific task. This model has the three relatively independent assessment processes that are involved iteratively in the formation of self-efficacy: analysis of task requirements, attributional analysis of experience and assessment of personal and situational resource (or constraints). The analysis of task requirements is an individual's assessment process that determines what it takes to perform a task. Individuals judge their skills, knowledge and abilities to perform required tasks successfully. This process also depends on novelty and direct experience with the task by an individual. If an individual experienced the task before, then the analyses processes become minimal. If the task is novel to an individual or the task was only indirectly experienced (i.e., the person watched others perform the task), then the task analyses would be extensive. The attributional analysis of experience is the assessment process through which the person judges his performance levels in regard to previous tasks accomplished successfully. If an individual performed the task successfully in the past, then he or she would be more likely to rely heavily on the causes of that performance level. This assumes that the extent to which the relevant skills, knowledge, effort and activities required to perform the task are similar to the ones of the previous level of performance, therefore leading to the success of the task. The analysis of the task requirements and the attributional analysis of experience together help an individual estimate what will be required to perform the task successfully with respect to ability, motivation and relative contribution to performance (Chowdhury, 2000). The assessment of personal and situational resources (or constraints)

is the consideration by an individual on his or her personal and situation resources available in terms of task accomplishment. The availability of resources and constraints may help or hinder an individual's performance of the tasks at various levels. The personal factors include skill level, desire, anxiety and availability of effort, while the situational factors include competing demands and distractions (Gist & Mitchell, 1992). Each assessment process in the model utilizes, weights and integrates different sources of information to form self-efficacy. Depending upon the nature of the task and the degree of an individual's experiences with the task, each process is weighted differently. Put together, a combination of these three assessment processes and four sources of self-efficacy function as determinants of the level of self-efficacy, which is directly related to performance outcomes.

Criticism of the self-efficacy theory include conceptual ambiguity, methodological problems and low predictability (Eastman & Marzillier, 1984, as cited in Redmond, 2010). The first criticism focuses on ambiguity and the lack of definitions for the constructs. Although Bandura (1977) claimed that self-efficacy and outcomes expectations are conceptually different in that people may believe that a particular course of actions will lead to certain outcomes, several researchers have argued that these constructs were not clearly defined or conceptually distinct, but, rather, very closely related to each other (Kazdin, 1978; Eastman & Marzillier, 1984, as cited in Redmond, 2010). Bandura stated that the outcomes were the results of certain behaviors with self-efficacy, while others viewed that expectations about outcomes result in self-efficacy. Namely, Bandura's view is a one-directional influence from self-efficacy to the outcome, while others' had views that were multi-directional, in spite of the intensity. Bandura

provided an example that showed that a snake-phobic individual's self-efficacy might alleviate the phobia, thus mediate the behavior change of lifting the snake. However, the counterargument to Bandura's example was that even individuals without a phobia of snakes would have the same low efficacy expectations when involved in lifting a snake, whether it is poisonous or harmless, due to the dreadful outcome expectation of being bitten by a snake. Therefore, the efficacy expectation would influence not only the behaviors of the individual, but also cause low self-efficacy, whether he or she possesses a phobia or the capabilities to perform the behavior.

Additionally, the construct of the outcome was ambiguously defined. In another example of jumping six feet (Bandura, 1977), the action of jumping can be interpreted as either an attempt or an outcome (ensuing social recognition, applause and trophies if succeeded). Successful completion of the jump was the outcome in itself of the previous task (attempt) and simultaneously became another attempt at a high jump. In this sense, the outcome was inevitably and closely related to the jumper's assessment of his or her self-efficacy. Therefore, it is difficult to develop an adequate explanation for behavior unless clearer definitions of self-efficacy and outcome expectations are provided (Eastman & Marzillier, 1984; Lee, 1994).

The second criticism focuses on the methodology problem, which does not show significant and generalizable relationships between Bandura's empirical findings and self-efficacy. Although Bandura claimed that the self-efficacy theory was considered to have advantages in regard to predicting behaviors in many settings, his empirical findings relied much on unobservable and unverifiable variables and processes (Lee, 1994; Skinner, 1977) and did not provide an explanation of the processes involved in the

behavior and behavior changes (Eysenck, 1978; Skinner, 1977, 1987, as cited in Lee, 1989). Self-efficacy develops from past experiences, vicarious experiences, verbal persuasion and physiological feedback. These four sources interact with each other to form the self-efficacy expectation. However, no explanation exists about how these sources of information are synthesized or to what extent in the process. The theory vaguely postulated (in an unspecified manner) that efficacy forms from the unobservable processes of synthesized information to produce observable behaviors. Thus, it is difficult to develop a model to predict efficacy expectations from these sources. Moreover, since no framework exists to describe how efficacy expectations interact with other variables, such as skill levels and incentives, which Bandura argued were important influential factors on behavior, no framework exists to predict what behaviors will result from a combination of skill levels, efficacy and incentives. Therefore, due to these weaknesses, it is very difficult to develop a framework that is practically applicable.

2.1.8. Self-determination Theory

In sports psychology, researchers have focused for nearly three decades on two types of motivations in the self-determination theory: intrinsic motivation (IM) and extrinsic motivation (EM) (Deci & Ryan, 1985, 1990, 2000; Vallerand & Ratelle, 1997). IM refers to involvement in an activity for internal constructs for a person, such as pleasure, enjoyment and satisfaction inherent in the activity (Deci, 1975; Deci & Ryan, 1985). For example, a young boy likes to play soccer because the activity gives him inherent enjoyment in learning to play. EM refers to a wide range of behaviors that are engaged in for external and instrumental reasons in order to attain outcomes, not for inherent reasons (Deci, 1971). This construct can be classified into four types of

motivations based on the degree of self-determination: external regulation, introjected regulation, identified regulation and integrated regulation. External regulation is the type of extrinsic motivation where acts are performed in order to achieve a positive state or avoid a negative end state, which are separated from the activity itself, such as working hard for a company to get money (to get a positive result) and following traffic rules (to avoid a negative result). Introjected regulation is the extrinsic motivation when actions are performed to internalize the reasons from their social environment in order to maintain self-esteem and pride or avoid guilt or anxiety. Namely, tensions or pressures exist if people do not carry out an action, such as donations that wealthy people perform due to feelings of guilt or voting in an election because of a person's feeling that it is his duty as a citizen. When acts are considered valuable to completing a person's objectives or goals, such as waking up earlier to study because she or he feels it is personally important to get higher score, it is identified as regulation.

The final type of extrinsic motivation is integrated regulation, where acts are performed because these acts represent who a person is or what he or she stands for, such as volunteering for a cause and, therefore, sacrificing his or her time. This regulation is the most self-determined type of EM. Amotivation (AM) refers to the status when people present a relative absence of motivation.

The theory of self-determination has been widely accepted and developed for more than 30 years because it has a clear prescription for how to motivate people to perform behaviors well, while also supporting their autonomy (Vansteenkiste & Sheldon, 2006). Namely, the theory explains with detailed classifications of motivation types how to motivate individuals who desire to achieve self-defined goals. Therefore, the theory

has been widely tested empirically and used practically in diverse domains, such as education, business, sports, unemployment and parenting (Deci, Koestner, & Ryan, 1999; Deci & Ryan, 2000; Vallerand & Ratelle, 1997). However, a lack of articulation of the construct of 'autonomy-support' and few applications in the fields of clinical psychology and psychological counseling are among the limitations of the theory (Vansteenkiste & Sheldon, 2006).

2.1.9. Summary of Theories of Motivation

This section covered the theories related to the constructs of motivation in order to better understand what motivation is, how it is shaped and how it affects the behaviors of an individual. Those theories are briefly summarized in Table 2, which illustrates the advantages and disadvantages of each theory.

Table 2. A summary of theories of motivation

Theories	Summary	+	-
Maslow's hierarchy of needs theory (Maslow, 1943)	• States that an individual tries to fulfill the needs from the bottom to the top in the hierarchy • Five basic hierarchical needs: physiological needs, need for security, need for belongingness and love, need for esteem, and need for self-actualization	• Simplicity and rationality, • Applicability to behaviors	• A lack of scientific evidence • Possible coexistence of needs at different levels • A lack of consideration on sociological context
ERG theory (Alderfer, 1969)	• Attempted to overcome the limitations of the Maslow's hierarchy of needs theory • Three needs: existence need, relatedness need, and growth need	• Allowing overlapping between needs • Flexible movements of the needs • Allowing to pursue multiple needs simultaneously	• A lack of scientific researches • Difficulty to measure what motivate people to behave a certain way specifically • Difficulty to determine the most important need
Acquired Needs theory (McClelland, 1965)	• Described how an individual's needs are shaped in individuals' life experiences over time and how those affect their behaviors	• Needs can be learned and developed in their life times. • Popularity and applicability (mainly because needs are correlated	• Limited applicability caused by cultural factors • A lack of predictive power (in entrepreneurship)

Theories	Summary	+	-
	• Three motivators: a need for achievement, a need for affiliation, and a need for power	to performance and needs can be developed through training and programs)	
Reinforcement theory (Skinner, 1974)	• Behaviors are shaped and learned by consequences of behaviors. If pleasurable rewards were followed, people would be more likely to perform certain behaviors. Reverse is also true. • Positive and negative reinforcement / punishment	• A large number of empirical researches • Practical applications in real world.	• Difficult identify accurate determinant of complex forms of behavior • Effectiveness fatigue of reinforcement over time • Limited applicability due to different personalities of individuals
Expectancy theory **(Vroom, 1964)**	• Explains the behavioral directions why an individual chooses one behavioral option among alternatives • Three components: Expectancy, Instrumentality, and Valence	• Consideration on not just internal factors of individuals but also external factors • Explains that people choose an action among alternatives in a manner that optimizes their expected valence	• The model is episodic and have difficulty explaining behaviors over time • Failed to show a high correlation between performance and reward (because performance can be influenced by other factors such as position.

Theories	Summary	+	-
Goal-setting theory **(Locke, 1990)**	• States that an individual's conscious goal leads to higher task performance. • Assumed that clear and realistic goals lead to higher probability of achievement and higher performance.	• A large number of empirical researches • Popularity, and simplicity	• Goal conflict when two or more goals simultaneously • Possible risk strategies to improve low performance • Possible failure caused by low self-efficacy • Ignorance of subconscious factor
Self-efficacy theory **(Bandura, 1977)**	• States that people with high self-efficacy tend to face the problems willingly, form a deeper commitment to the activities, develop skills and knowledge, and recover quickly from failures or disappointments	• Applicability and predictability of behaviors in many real world settings • Quick and easy administration for outcomes such as increase of performance and confidence.	• Ambiguity of constructs due to heavy reliance on unobservable and unverifiable processes • Methodological limitation which failed to show significant and generalizable relationship • Low predictability caused by a lack of explanation about other influential factors
Self determination theory	• Focused on individual's natural or intrinsic tendencies to behave in effective	• A large number of empirical researches • Practical	• A lack of articulation of construct of 'autonomy-support'

Theories	Summary	+	-
(Deci & Ryan, 1985)	and healthy ways as well as consideration on external factors • Intrinsic motivation and extrinsic motivation	applications in diverse domains	• The least number of applications in the fields of clinical psychology and psychological

2.2. Behavior Change

This section discusses the theories and models that focus on the relationship between the construct of motivation and behavior (i.e., how motivation is connected to actual behavior in its creation, change, maintenance and removal). The theory of reasoned action / planned behavior, the transtheoretical model and Fogg's behavioral model are presented.

2.2.1. Theories of Reasoned Action / Planned Behavior

The theory of reasoned action (Ajzen & Fishbein 1980) states that the behavior of an individual is determined by the individual's intention to perform the behavior. The intention is an important factor in determining one's behavior and behavior change. The intention develops from an individual's perception about the behavior, regardless of whether it is positive or negative, as well as from his or her considerations of society's perception about the behavior. In other words, individual intention to perform behaviors and social norms about the behavior (social environmental influences he or she may

experience) are two main factors in determining one's intention. The theory of reasoned action assumes that people have volitional control over the behavior of interest, meaning that people have the capability to perform the behavior whenever they want to. However, since the behavior of interest appeared not to be entirely volitional and under control, the theory of planned behavior (TPB) was proposed. It includes the construct of perceived behavior control not only to explain the case where behavior is not under control, but also to strengthen the predictive power of behavioral intention and behavior adoption (Ajzen, 1991). As a result, the theory emphasizes the construct of intention in behavior performance as the theory of reasoned action did, and covers the cases where an individual is not in control of all of the factors that affect the actual performance of a behavior.

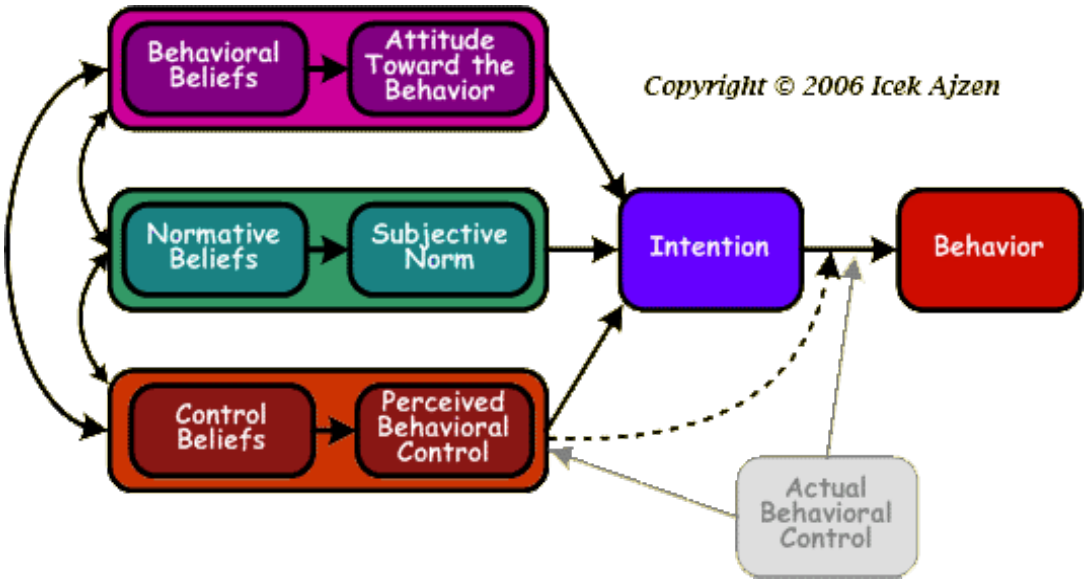

Figure 3. The TPB diagram (Ajzen, I., 1991). Retrieved March 10, 2014, from: people.umass.edu/aizen/tpb.diag.html.

The TPB distinguishes three types of beliefs: behavioral, normative and control. These three types of beliefs are comprised of six key elements, which correspond to an individual's actual control over the target behavior: behavioral belief, normative belief, control belief, attitude toward behavior, subjective norms, perceived behavioral control, and intention, as shown in Figure 3.

Behavioral beliefs refer to the belief that a behavior is related to certain outcomes. If a person performs a specific behavior, then he or she relies on the subjective probability that a perceived outcome will occur as a result of the behavior performed. Attitude toward behavior refers to the extent to which an individual has a positive or negative evaluation about the performance of a target behavior. This is determined by the total set of accessible behavioral beliefs linking the behavior to various outcomes and other attributes.

The normative belief type consists of normative beliefs and subjective norms. Normative beliefs refer to an individual's perception of social normative pressure or judgment of importance relevant to others or groups – whether they approve or disapprove a particular behavior. Subjective norm refers to an individual's perception or opinion about what others believe it is important whether she or he should perform a certain behavior. This is determined by normative beliefs concerning the expectations of important others.

The third belief type, control beliefs, refers to a person's beliefs about the perceived ease of performing the behavior or the obstacles preventing it. If a person has a stronger perceived control belief, then the person should have a stronger intention to perform the behavior. Perceived behavioral control refers to an individual's perception

about his or her ability to perform a given behavior. This is similar to the construct of self-efficacy. However, this perceived behavioral control varies based on the situation and accessible actions. It is assumed that the perceived behavioral control is determined by the total set of accessible control beliefs.

Finally, intention refers to how much a person is ready to perform a given behavior. It is considered to be the immediate antecedent of behavior. Behavior is the observable response in a given situation. Although perceived behavioral control is conceptually considered to moderate the effect of intention on behavior, both intentions and perceptions of behavioral control are, in practice, the main effects on behavior.

Although the theory of planned behavior has several strengths, such as coverage on non-volitional behavior, strong predictability of intention, consideration of the construct of social norms and addition of perceived behavioral control, which can explain the relationship between behavioral intention and actual behavior, it also has limitations. First, the theory of planned behavior overlooks the impact of other personal, cultural and demographic factors, such as personal emotions or religious beliefs, which can significantly influence behaviors and which lead to lower predictability, especially for health-related behaviors (Sutton, 2001; Dutta-Bergman, 2005, as cited in Munro, Lewin, Swart, & Volmink, 2007). The second limitation is that a significant time gap may exist between the assessment of a behavior intention and the assessment of the actual behavior. Therefore, it is possible that the intention of an individual might change (Werner 2004). The third limitation is that behavior in the theory was mostly measured by self-reporting rather than by an objective measure (Ogden, 2003). Answering this, Ajzen and Fishbein

(2004) defended that it is virtually impossible to measure some behaviors objectively and extremely expensive and time consuming for others (Sharma & Kanekar, 2007).

2.2.2. The Transtheoretical Model (TTM)

The transtheoretical model (Prochaska & DiClemente, 1983) conceptualizes the process of the intentional behavioral change of an individual. The model posits that individuals change their behaviors through five continuous stages: precontemplation, contemplation, preparation, action and maintenance. In the precontemplation stage, people do not have any intention to change their behaviors. People in this stage are not aware that their behaviors are problematic or that their behaviors result in negative consequences. They tend to undervalue the benefits of behavioral change, while overvaluing the negative consequences. In the contemplation stage, people are aware that their behaviors may be problematic and consider the pros and cons of changing their behaviors. In spite of their recognition, their degree of intention for behavior change is not enough to take action, but it is possible that this might occur in the near future (within the next six months). In the preparation stage, people make a commitment to change their behaviors or become ready to perform actions within the next 30 days. In the action stage, people start to become involved in changing their behaviors and taking action. They tend to learn how to strengthen and keep their commitments to changing their behaviors. In the maintenance stage, people sustain the change for the long term (for six months or more). The assumption of the model is that an individual's behavior change does not occur quickly or decisively, but occurs continuously in phases. Therefore,

different interventions and strategies are required for people in each stage in order to enable them to proceed to the next stage of change.

According to the TTM, there are ten processes of change that people employ to move from one stage to the next. The first process, consciousness raising, describes the process that people use to increase their awareness of their behaviors. The second process, dramatic relief, focuses on intensifying their emotional experiences, whether positive or negative, via methods such as role-playing. Self-reevaluation is the third process, in which people assess themselves with and without their behaviors, using methods such as imagery. The fourth process, environmental reevaluation, is the process in which people realize how behaviors affect their social environments, such as family interventions. The fifth process, social liberation, is the set of environmental opportunities that support behavioral of changes, such as the introduction of smoke-free zones. The sixth process, self-liberation, is the belief that one can achieve the behavior change. This process is similar to self-efficacy. Helping relationships is the seventh process, which describes supportive relationships that encourage the desired change, such as community forums of individuals committed to smoking behavior changes. Counter-conditioning is the eighth process in which one substitutes behaviors and thoughts, such as replacing tobacco with an e-cigarette. The ninth process is reinforcement management, which rewards results from positive behaviors, while it punishes results from negative behaviors. The last process, stimulus control, is the process of manipulating environments to provide reminders and cues to encourage the positive behaviors, while removing the negative behaviors.

Strengths of the transtheoretical model include a large number of empirical studies, generalizability and applicability. Since the model was developed from the systematic integration of more than 300 theories of behavior change (Prochaska & Velicer, 1997, as cited in Lenio, 2006), the theory has been empirically proven and validated. Also, the TTM model showed successful generalizability across a wide range of problem behaviors, such as smoking cessation, quitting cocaine, adhering to high-fiber diets and exercise acquisition (Prochaska et al., 1994, as cited in Lenio, 2006). The applicability over a range of populations is an additional strength of the TTM model (Marcus & Simkin, 1993; Prochaska & Marcus, 1994; Cardinal, 1995; Buxton, Wyse, & Mercer, 1996, as cited in Rodgers et al., 2001).

Meanwhile, limitations of the transtheoretical model also exist (Sutton, 2001; Littell & Girvin, 2002; Adams & White, 2005; West, 2005). First, the dividing lines between the stages are arbitrary. Namely, stages of change are not mutually exclusive and overlaps may exist. This is because there are no set criteria by which to determine each stage of change for an individual. The questionnaires and algorithms that researchers have used to assign an individual to a stage of change have not been standardized or validated. Furthermore, it is not clear how much time is needed for each stage of change or how much time an individual can remain in each stage. Although six months in the maintenance stage and 30 days in the action stage are frequently used in research, these durations have not been validated.

2.2.3. Fogg's Behavior Model (FBM)

The FBM model (Fogg, 2009) seeks to explain behavior changes. According to Fogg, behavior is the result of three factors: motivation, ability and triggers. Each factor must occur simultaneously to result in a person performing a behavior. In other words, a person should have enough motivation, sufficient ability and effective triggers in order to perform a behavior. If people have high motivation, but low ability – for instance, when purchasing an expensive product online – a purchasing behavior would not occur. Inversely, if people have a high ability to purchase an expensive product, but have low motivation, the behavior would also not occur. Even when people have both high motivation and high ability to perform an action, a behavior would still not emerge unless there is an appropriate and effective trigger. A possible example is a member of a fitness club who wants to lose weight and has the abilities (e.g., time and money), but goes to the club irregularly. In this case, a text that highlights the danger of obesity or a video that inspires a hope to become healthy is going to be an effective trigger. It is important that the trigger should be well-timed in order to lead to an emergence of a desired behavior.

Fogg also specified the subcomponents of each factor that are used to better understand behavior change. Motivation has subcomponents of pleasure-pain, hope-fear and social acceptance-rejection, whereas ability is comprised of time, money, physical effort, brain cycle, social deviance and non-routineness. The sub-elements of trigger are spark, facilitator and signal. When applying the concept of ability in the FBM model to the design of persuasive systems, it is often related to the 'simplicity' of tasks. That is, instead of increasing the ability of people, it is recommended to design tasks to be easier

to accomplish in order to facilitate behavior change. For example, 1-click shopping on Amazon has led more people to purchase more products.

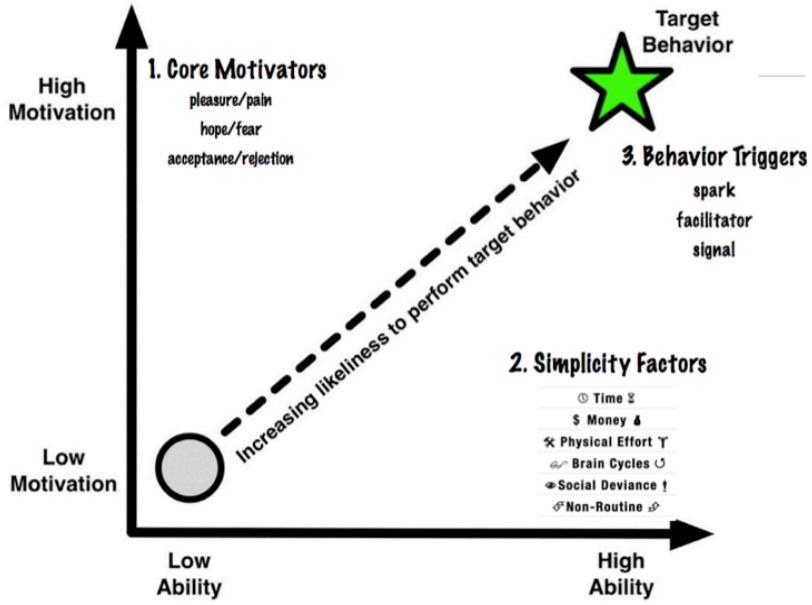

Figure 4. The Fogg Behavior Model (FBM) has three factors: motivation, ability, and triggers. Each factor has its subcomponents (Fogg, 2009)

The strengths of the FBM model are its simplicity, allowing researchers and designers to easily understand and consider factors underlying behavior change (Lawley, 2013), and its applicability to a variety of domains, such as healthy behavior and study habits (Chen, Goh, & Abdul Razak, 2012; Hedin, 2012, as cited in Allen, 2013). One limitation of the FBM is that it has been used to design persuasive technologies primarily for adults. It is less clear how the FBM principles can be effectively applicable to persuasive technologies used to facilitate behavioral changes in children or adolescents (Allen, 2013). Another limitation is the fact that the model cannot explain situations where one does not perform a behavior although the conditions of the three factors are otherwise fulfilled (Lawley, 2013). Namely, one sometimes performs a certain behavior

because he or she is highly motivated, has ability and received a trigger. However, at other times, the person does not perform the behavior despite the existence of these three factors. There are possibly other internal or external factors that affect the initiation of his or her behavior.

2.2.4. Summary of the Theories of Behavioral Change

This section covered the theories and models about behavior change. Those are briefly summarized in the table 3 with its advantages and disadvantages.

Table 3. A summary of theories of behavior change

Theories	**Summary**	+	-
Theory of reasoned action / planned behavior (Ajzen & Fishbein, 1980)	• States that behavior of an individual is determined by one's intention to perform the behavior Key components: behavioral belief, normative belief, control belief, attitude toward behavior, subjective norms, perceived behavioral control and intention	• Coverage on non-volitional behavior • Better predictability of intention • Consideration on a construct of social norm • Addition of perceived behavioral control	• Ignorance of impacts of other personal, cultural and demographic factors • Significant time gap between assessment of behavior intention and assessment of the actual behavior • Non-objective measure of behavior (mostly measured by self reports)

Theories	Summary	+	-
Transtheoretical Model **(TTM; Prochaska & DiClemente, 1983)**	• Conceptualizes the process of intentional behavioral change of an individual States that individuals change their behaviors through five continuous stages: precontemplation, contemplation, preparation, action, and maintenance	• A large number of empirical researches • Generalizability and applicability across a broad range of problem behaviors as well as a variety range of population	• Dividing lines between the stages are arbitrary • Methodological problem (questionnaires and algorithms were not standardized or validated) • Unclear description of how much time is needed for each stage of change or how much time an individual can remain in each stage
Fogg's Behavior Model **(FBM; Fogg, 2009)**	• States that behavior is result of three factors: motivation, ability, and triggers, and each one must occur simultaneously to result in performing a behavior	• Simplicity • Applicability in a variety domains	• Limited applicability across age • Exception exists although all three factors are met (Possibly other factors exist)

Based on the literature review, it seems like a framework that incorporates the advantages of the transtheoretical model's stages of behavior change (Prachaska & DiClementa, 1983) and the idea of triggers from FBM (Fogg, 2009) would be the most fruitful because it would explain both the motivational changes at each stage of behavior change when the persuasive elements are provided and how effectively the persuasive elements are combined to positively and incrementally motivate users toward a target behavior.

2.3. Persuasive Technology

Persuasion is the human interaction that continuously tries to influence others' behaviors and attitudes. As Fogg (1999) stated, it is neither coercive nor deceptive interaction, but requires an intention to influence others' attitudes, behaviors or both. The persuasion activity is widely presented in everyday life in persuasive messages, such as those on voting, diet, exercise, smoking, TV and Internet use, energy consumption and stress management. With the distinctive advantages of computers and systems over humans, including interactivity, persistency, anonymity, timeliness, modality and ubiquitousness (IJsselsteijn, 2006; Fogg, 1999; Fogg, 2002), various persuasive technologies, models, strategies and approaches have been explored and developed to amplify a system's persuasive power. This chapter first discusses persuasive strategies and design principles for the development of persuasive technologies and then presents practical examples of persuasive systems across four domains: marketing, safety, environmental conservation and health.

2.3.1. Persuasive Strategies

This research reviews the six most important persuasive strategies and design principles found in the literature in order to provide a better understanding of what persuasive elements are required to have effective persuasive power in the system.

King and Tester (1999) classified the five basic persuasive strategies that people have applied in attempts to change others' attitudes and behaviors since long before technologies and computers were part of everyday life. Those strategies are: simulated experience, surveillance (monitoring and tracking), environment of discovery, virtual group and personalization. Simulated experience is the strategy that uses a simulated environment or object similar to its real counterpart. Improvements in people's decision-making in a simulated environment can result in positive consequences in the real world, while bad decisions result in negative outcomes. Experiencing the consequences resulting from their decisions in the simulated environment affects their behaviors and attitudes. Surveillance uses the strategy of monitoring and tracking to influence people's behaviors and attitudes. When someone recognizes that he or she is being tracked or monitored, then his or her attitudes and behaviors are significantly affected. Although there are concerns about an individual's freedom and privacy, this surveillance strategy is frequently used to benefit the majority, such as the surveillance camera and the Hygiene Guard, a persuasive monitoring device in restaurants to encourage employees to wash their hands after bathroom use (King & Tester, 1999). The environment of discovery is a strategy that provides people with a fantasy environment in which they are able to explore, exert control over the environment and receive positive feedback (rewards) when they perform target activities. This differs from the simulated experience in that the

environment of discovery focuses more on characteristics of control, fantasy and positive feedback, while placing less consideration on negative simulated consequences. The virtual group strategy motivates people to achieve certain tasks through collaboration and competition with others in a group setting. Personalization is the strategy that tailors the information to people to affect their behaviors and attitudes by trying to match individual interests and concerns.

Fogg (2002) presented seven types of persuasive strategies to use in computer systems to change people's behaviors and attitudes: reduction, tunneling, tailoring, suggestion, self-monitoring, surveillance and conditioning. Reduction refers to a strategy to reduce complex behavior tasks into simple tasks. Tunneling guides the user through predefined processes or sequences of experiences in an interactive system. Tailoring is a strategy used to provide information that is tailored to individual needs, interests, personalities and usage contexts. This strategy has been acknowledged as one of the most potentially powerful persuasive strategies in e-commerce. The suggestion strategy intervenes in the user's activity at the most opportune moments and in the right contexts. The self-monitoring strategy allows users to monitor themselves and evaluate their progress toward outcome goals. Surveillance is used when the observation of certain behaviors increases the chance of changing behaviors or attitudes. Conditioning is the reinforcement to the target behaviors in a positive way. When paired with rewarding stimuli, conditioning will increase the likelihood of desirable behaviors in frequency and intensity.

Cialdini (2001) also presented six persuasion principles: liking, reciprocity, social proof, consistency, authority and scarcity. The liking principle refers to a situation in

which people choose the product not just because they like the product itself, but also to please those individuals whom they like. Research has identified two core elements among the several factors that reliably increase liking: similarity and praise. The reciprocity principle refers to the fact that people tend to treat other people the way they were treated. This suggests that the designer of the persuasive system should provide what they want to receive from the users. Social proof indicates that people in many situations depend heavily on those people around them to look for cues on how to think, feel and act. Namely, people tend to look to the behaviors of the people around them when they face uncertainty to guide their courses of action. This phenomenon occurs more frequently when they follow the lead of similar others, especially friends, peers and neighbors, with whom they are familiar than with random strangers. The consistency principle means that people strive for consistency in their commitments. People tend to behave so that they appear consistent to others. Specifically, people are more likely to behave after they have agreed to do so verbally or in writing. This suggests that a persuasive system should provide users the chance to make their commitments active, public and voluntary. Authority is based on the idea that people defer to authority. People tend to follow opinions and advice of experts on certain topics, such as legal, financial, medical or technical fields, especially when viewed in the media. Presenting authority and credibility in the persuasive system will increase the likelihood of users to follow and respond to a system's persuasive requests. Scarcity is a principle of persuasion based on the idea that the more rare the items and opportunities are, the more valuable they are. This suggests that emphasis on a possible loss in the persuasive system is sometimes more effective than emphasis on possible gains.

Arroyo, Bonanni and Selker (2005) identified seven design principles for persuasion techniques and feedback, which influence behavior change at increasing cognitive levels: value-added design, automation, just-in-time prompts, positive reinforcement, negative reinforcement, adaptive interfaces and social validation. Value-added design is the principle that adding perceived value – even a small amount – to a product can lead to a behavior change. It also makes a system user feel that the product is more valuable and attractive. Automation is a principle that states that making the system automated will directly influence a system user to change his behaviors to achieve a task quickly and easily. This principle aligns with the FBM model's ability factor. The principle of just-in-time prompts states that reminding people with visual and auditory aids at the right time will affect behavior change. The prompts should be clear, explicit and presented at the appropriate time and place without annoying the user. Research has shown that effective use of just-in-time prompts fosters sustainable behavior changes (Aitken, McMahon, Wearing, & Finlayson, 1994; Aronson, 1983; Arroyo, Bonanni, & Selker, 2005; Intille, Farzanfar, & Bakr, 2003; Russell, Dzewaltowski, & Ryan, 1999). The positive reinforcement principle is based on the idea that positive stimulus and consequences, which people repeat intentionally, can lead to behavior changes. Possible examples are providing rewards and showing people desirable consequences for their actions. Conversely, the negative reinforcement principle uses negative stimuli to change the behavior(s) of people. For example, showing a heavy smoker a picture of the lung of a smoker with lung cancer is more likely to cause him or her to consider quitting smoking. However, it is important to carefully use negative reinforcement at an appropriate level in order not to irritate or annoy people. The adaptive interfaces principle states that

interfaces should be adaptive according to a user's current stage of behavioral modification. If people were accustomed to the interface and able to expect its consequences, then they would be less influenced and possibly annoyed by it. Therefore, adaptive interfaces should vary in their modality and frequency to be effective. Social validation is based on the idea that people are social animals and influenced by their peers. They tend to determine what is correct according to what others consider correct, regardless of the truth. The more people think something is correct, the more correct it becomes. This principle is similar to Cialdini's social proof principle.

Similarly, Liu, Helfenstein and Wahlstedt (2008) proposed a design model for a persuasive agent, which would guide people's behavior changes. Their design model is made up of five communication skill-relevant elements that the agent needs to have: agreeableness, anthropomorphism, informativity, persuasiveness and adaptivity. Agreeableness indicates that the agent should be kind, sympathetic, warm and cooperative, as well as possess a friendly appearance and eloquent communication style. Therefore, users are able to feel comfortable and willing to interact with the agent. The anthropomorphism element indicates that agents with human traits are more likely to be attractive to users than machine-like ones. This element is based on the fact that the anthropomorphic representation serves as a set of easily identifiable behavioral cues for social interactions (Hargie, 1997; King & Ohya, 1996; Takama, Dohi, & Ishizuka, 1998). Informativity states that the advice or decisions provided by the agent should be useful, necessary and sufficient to users and justified with rationales or explanations. Otherwise, the information from the agent is not valuable, assistive or relevant to users. Also, the agent should not provide users with too much information as to not overwhelm them or

make them impatient. The persuasiveness element points out that the agent should possess persuasive cues, which induce social influence, pertaining to the influence schemes of request justification, reciprocation, commitment and consistency, social proof, liking, authority, and scarcity (Cialdini, 1984). However, the agent should not make users feel that they are being explicitly persuaded. The adaptivity element indicates that the collaboration styles and skills of the persuasive agents and users' preferences in the agents should be adaptable and must evolve.

Oinas-Kukkonen and Harjumaa (2009) proposed a set of design principles for persuasive systems, which extended the FBM model to practical design requirements, since they observed that the FBM model did not clearly explain how its principles and conceptualization can be applied to actual practical software design and development processes. Their proposed principles fell into four categories: primary task support, dialogue support, system credibility support and social support. The first category, as the name suggests, the primary task support category describes how a persuasive system supports the primary task of the users in performing the target behavior. This category includes principles of reduction, tailoring, tunneling, personalization, self-monitoring, simulation and rehearsal. The reduction principle states that people would be more likely to perform the target behavior if a system reduces the complexity of the tasks into a simple one, thus increasing the cost-benefit ratio of undertaking a behavior. In other words, a persuasive system should reduce the complexity of the tasks so that the users perform the target behavior with less effort. The tailoring principle states that people would be more likely to be persuaded if a system provided the information tailored to the user's potential needs, interests, personality, usage context or other relevant factors. Thus,

a persuasive system should provide differently tailored information and contents to different user groups, such as beginner and expert users. The tunneling principle states that users would be more likely to be persuaded if a system guided them through the process to perform the target behavior. The personalization principle states that people would be more likely to be persuaded if a system offers personalized content and services. This suggests that a persuasive system should provide the means by which users can personalize and customize the contents so that they have a greater persuasive effect. The self-monitoring principle states that people would have a higher chance to achieve their goals if the system provided a ways by which to check their own performance. Therefore, a persuasive system should provide users with a means by which to track their status or performance in order to support achieving their goals. The simulation principle states that people would be more likely to perform the target behavior if the system offered an immediate relationship between the cause and effect of the behavior in the simulated environment. This indicates that a persuasive system should provide a means by which to immediately observe the cause and effect relationships with regard to the behavior. The rehearsal principle states that if the system provided ways to practice and rehearse a certain behavior, then users would be more likely to change their behaviors and attitudes in the real world. Thus, a persuasive system should provide a means to rehearse a target behavior.

The second category, dialog support, helps users to achieve their goals through human-computer dialogue and is partly adopted from the social actors concept in the FBM. This category includes principles of praise, rewards, reminders, suggestion, similarity, liking and social role. The praise principle states that people would be more

open to persuasion if they received praise, which indicates that persuasive systems should provide praise and positive feedback via words, images, symbols and sounds as a way for users to open up to persuasion. The rewards principle is the idea that people would be more likely to perform the target behavior if they receive rewards, which suggests that a persuasive system should provide users with virtual rewards for performing a target behavior. The reminders principle states that people would be more likely to perform the target behavior and achieve their goals if the system reminded them of their goals and behaviors. As such, a persuasive system should provide users with reminders to perform target behaviors that will lead them to achieving their goals. The suggestion principle states that a system offering suggestions at the right moment and in the right context will have more persuasive power, which indicates that a system should provide suggestions at the opportune moments to encourage the performance of certain behaviors. The similarity principle states that people would be more likely to perform a certain behavior if they found similarity to them in the system, which suggests that a persuasive system should provide certain common characteristics similar to users in some specific way. The liking principle states that a system would have more persuasive power if it had a look and feel that appeals to its users, which is based on the idea that people are more persuaded when a system is more visually attractive. The social role principle indicates that people would use a persuasive system more if it adopted a social role, such as an E-health application adopting a social role mediating the conversation between a user and his health specialist.

The third category, system credibility, describes a relationship between the credibility of a persuasive system and persuasiveness. The underlying assumption is that a persuasive system would have more persuasive power if it has credibility. This category

includes trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements and verifiability. The trustworthiness principle says that a system that a user considers as being trustworthy is more likely to have increased persuasive power, which suggests that a system should provide information and contents that are trustful, fair and unbiased so that users will feel that the system is more trustworthy and, therefore, more persuasive. The expertise principle states that a system having expertise (knowledge, experience and competence) is more likely to have more persuasive power. Surface credibility says that a system should have an attractive look and feel because people assess the credibility of a system at first glance. The real-world feel principle states that a system that provides contents and information that other people or organizations stand behind will have more credibility and persuasive power, which indicates that a system should provide content and information from actual organizations and people in order to have more persuasive power. The authority principle says that having authority embedded in a persuasive system will make a persuasive system have enhanced power of persuasion. This statement suggests that a system should refer to people in the role of authority in order to have more credibility. The third-party endorsement principle says that a persuasive system should provide third-party endorsements from well-known and respected sources in order to lead the user to perceive the system as being more credible. The verifiability principle states that users will perceive a persuasive system as credible if it provides users with an easier way to verify the accuracy of the content and information via outside sources.

The last category, social support, describes how a persuasive system should leverage social influence to have more persuasive power. This category includes the

principles of social facilitation, social comparison, normative influence, social learning, cooperation, competition and recognition. The basic idea of these principles is based on Fogg's principles on mobility and connectivity. The social learning principle states that people are more likely to perform the target behavior if a persuasive system provides a means of observing others performing the same behavior. Thus, a persuasive system should provide a way to observe other users performing the target behavior as well as a way to see the outcomes of the behavior. The normative influence principle states that people are more likely to adopt a target behavior if a system can leverage normative influence or peer pressure. The social facilitation principle states that users of a persuasive system are more likely to perform a target behavior if they discern others performing the same behaviors along with them. The cooperation principle states that cooperation helps users perform a target behavior because it is in human beings' natural drives to co-operate, which suggests that a persuasive system should provide ways to work with others to achieve target goals. The competition principle states that competition, another natural drive of human beings, can motivate users to perform a target behavior when competition is more beneficial than collaboration. The recognition principle states that people would be more likely to perform a target behavior if a system offered public recognition for an individual or a group. Therefore, it suggests that a persuasive system should provide users ways to discern others performing the behavior, a means by which to compete themselves with other users, ways to gather users together who have common goals and a public recognition to perform the target behavior, such as virtual rankings or a user of the month.

Table 4 shows an overview of the persuasive strategies and principles, together with a short description of each principle.

Table 4. An overview of persuasive strategies and principles

Principles	Components	Description
King & Tester's five persuasive strategies (1999)	Simulated experience	Uses the simulated environment or object similar to real counterpart
	Surveillance	Uses the strategy of monitoring and tracking to influence on people's behaviors and attitudes
	Environment of discovery	Provides people fantasy environment where they are able to explore, control over the environment, and receive positive feedback (rewards) when they perform target activities
	Virtual group	Motivates people to achieve certain tasks through collaborate and compete with others in a group setting
	Personalizing	That tailors the information to people to affect their behavior and attitudes by trying to match individual interests and concerns
Cialdini's six persuasion principles (2001)	Liking	Shows people similarities and offer praise
	Reciprocity	Provides what people want to receive.
	Social proof	Indicates that people tend to behave based on social cues around them
	Consistency	Means that people strive for consistency in their commitments.
	Authority	Indicates that people tend to defer to authority
	Scarcity	Assumes that people tend to give more value to rare items

Principles	Components	Description
Fogg's seven types of persuasive strategies (2003)	Reduction	Reduces complex behaviors tasks simple tasks
	Tunneling	Guides the user through predefined processes or sequence of experience in the interactive system
	Tailoring	Provides information that is tailored to individual needs, interests, personality, and usage context
	Suggestion	Intervenes in the user's activity at the most opportune moments and the right context
	Self-monitoring	Allows users to monitor themselves and evaluate their progress toward outcome goals
	Surveillance	Used when observation of certain behaviors increases the chance of changing behavior or attitudes
	Conditioning	Uses reinforcement for the target behaviors in a positive way
Arroyo, Bonanni & Selker's seven design principles for persuasion techniques and feedback (2005)	Value-added design	Indicates that perceived value lead to one's behavior change
	Automation	Indicates that automation directly affect users to change behaviors to achieve task quickly and easily
	Just-in-time prompts	Indicates that reminding people with visual and auditory aids at right time affect behavior change
	Positive reinforcement	Uses positive stimulus and consequences to increase positive behavior
	Negative reinforcement	Uses negative stimulus to reduce negative behaviors
	Adaptive interfaces	Indicates that interface should be adaptive according to one's stage of behavioral modification

Principles	Components	Description
	Social validation	Bases on that people are social animals and influenced by other peers
Liu, Helfenstein, & Wahlstedh's design model for persuasive agent (2008)	Agreeableness	Indicates that the agent should be agreeable possessing a friendly appearance and eloquent communication style
	Anthropomorphism	Indicates that agents with human traits are more likely to be attractive to users than machine-like ones
	Informativity	Indicates that the advice or decisions provided in the agent should be useful, necessary and sufficient to users and justified with rationales or explanation
	Persuasiveness	The persuasive agent should possess persuasive cues
	Adaptivity	Indicates that collaboration styles and skills of the persuasive agent should be adaptable and must evolve in it
Oinas-Kukkonen & Harjumaa's design principles for persuasive systems (2009)	Primary task support	Describes how a persuasive system supports the primary task of the users to perform the target behavior
	Dialogue support	Helps users achieve their goals by human-computer dialogue and is partly adopted from social actors concept in the FBM
	System credibility support	Describes that credibility of a persuasive system increases persuasive power
	Social support	Describes how a persuasive system should leverage social influence to have more persuasive power

2.3.2. Persuasive Technologies in a Variety of Domains

King and Tester (1999) classified twelve domains in which persuasive technologies could have a significant impact. This chapter reviews practical examples of persuasive systems in the four most significant domains: marketing, safety, environmental conservation and health.

2.3.2.1. Marketing Domain

One simple example of persuasive technology in the marketing domain includes the recommendation systems on e-commerce sites, such as eBay and Amazon. These systems try to persuade users to purchase similar or interesting items by showing them a list of recommendations through collaborative or content-based filtering (Jafarkarimi, Sim, & Saadatdoost, 2012). Namely, information about the user is compared to other users, while the user's purchase information, such as the genre of music or books purchased, is compared to the purchase information of other users. Senecal and Nantel (2004) showed that consumers' online product choices were more influenced by impersonal recommendation systems providing personalized product information than by traditional recommendation sources, including human experts and other consumers, which is one of the reasons why persuasive systems have been widely adopted in this domain.

Another example is the iCart (Kallehave, Skov, & Tiainen, 2010), a persuasive shopping trolley, which provides consumers simple nutrition classifications of food products in a grocery store. Consumers often find it difficult to assess the nutritional value of the products they purchase in a supermarket and tend to stick with familiar food

products even though they are unhealthy (Kallehave, Skov, & Tiainen, 2010). Every time a consumer puts a product on the trolley, the iCart provides a simple classification of the product into one of three categories: Eat Most, Eat Less and Eat Least. The iCart also adapted two persuasive design principles from Fogg (2002): reduction and suggestion. The reduction principle basically transforms complex behaviors into simple tasks so that iCart can provide nutrition information in a simple way – color-coding the three categories for consumers to assess the food products easily. The suggestion principle suggests that a system would have greater persuasive power if it provided suggestions at the appropriate time. When the consumer chooses an item in the Eat Less or Eat Least categories, the iCart offers suggestions for alternative food products in the Eat Most category. The evaluation results showed that the reduction element of the iCart was successful, while the suggestion element was not. The reasons were that some of the consumers tended to implement their own classification schemes and were more reliant upon other aspects, besides nutrition information, and that they preferred unhealthier products even when there were products of zero and lighter calories available and they were made aware of the nutritional discrepancies.

2.3.2.2 Energy Conservation Domain

PowerHouse (Bang, Torstensson, & Katzeff, 2006) is one of the persuasive computer games in the energy consumption domain attempting to influence household energy consumption behaviors. It explored various ways to provide information about adopting an energy-saving lifestyle in a fun and rewarding way, both explicitly and implicitly. A player of the game needs to manage a simulated domestic environment

where seven virtual characters reside, having different personalities and basic needs. The basic objective is to meet these characters' needs and wishes and let them reside within the house as long as possible. Then, the other objective is to nourish the house by directing virtual characters to perform energy-efficient actions, such as using less water when taking a shower, watching television less and using less electricity when cooking. The more energy-efficient actions are performed, the more virtual money is given to the player. The player can use the virtual money to purchase artifacts and services that can lead to the house becoming more energy efficient. Therefore, the player is able to not only learn energy-efficient behaviors in the short-term, but also to have a chance to modify their behaviors and attitudes toward a more energy-efficient lifestyle in the long-term.

WattsUp is another persuasive technology application in the domestic energy consumption domain, which uses a social networking site (Facebook) as a persuasive element, combined with the Wattson device, a consumer product that monitors domestic electricity usage (Foster, Lawson, Blythe, & Cairns, 2010). The concept of the WattsUp application is that a user's current energy usage, measured from the Wattson, is sent to the WattsUp application. Then a user is able to see the previous and current energy usage represented numerically and graphically. It also provides the user with visualizations of the energy usage of his or her Facebook friends who also participate in the WattsUp application and use the Wattson device. A ranking table of users with the highest and lowest energy consumption is also included in the application as a socially persuasive element. Therefore, the application promotes not only the concept of social competition, where users (moderately) compete with each other by lowering their energy usage, but

also the concept of social learning, where users are able to learn new behaviors, habits and attitudes by observing others, thus having a positive impact on the environment. In their initial user study, although some users expressed negative opinions about the issues of privacy concerns and confusion with the interface, the majority of the users found that the application was easy and simple to use, even for non-technical people. They also found that social elements within the application were able to lead to competition and peer influence that encouraged the participants to reduce their energy usage. In their second study, the WattsUp application and the Wattson energy monitor were deployed in eight homes with 20 subjects in two conditions for a period of 18 days. The first condition had the social competition element (socially enabled condition) that subjects could access both their energy usage data as well as their friends' data. In the second condition (the socially disabled condition), they only had access to their own data. The quantitative and qualitative analysis of the second study revealed that significantly lower energy consumption and a significantly higher number of visits to the WattsUp application were observed in the socially enabled condition. The participants spent most of their time on the ranking page, indicating that the competitive aspect of the ranking was enjoyable to them. All of the participants preferred the socially enabled condition and showed willingness to use the system over a longer period of time. The authors of the paper claimed that social networking sites could possibly play an important role in reducing energy consumption since it has the persuasive element of social competition, which helped motivate energy savings more effectively and enjoyably for the participants.

Froehlich et al. (2009) developed the UbiGreen Transportation Display prototype, a mobile phone application that semi-automatically senses personal transportation activities of the users and provides them feedback on additional reasons for being green. Once the users' eco-friendly transportation activities are sensed, such as riding the bus or train, walking, biking or carpooling instead of driving alone, the application updates the interface on the background of the user's phone. The interface shows a series of images of either a tree or polar bears to indicate the level of green transportation activities being carried out. In one interface, a tree will grow and have leaves, blossoms and apples according to accumulation of the users' green transportation activities. In another interface, a small iceberg in the center of the screen will grow, the number of polar bears will increase and food sources, such as fish and seals, will appear as green transportation actions are taken. In both designs, there are four icons at the bottom of the screen: a piggy bank, a person mediating, a weightlifter and a book. Each icon represents the most recent green activity and other potential benefits. A piggy bank is an icon representing financial savings due to taking less expensive public transportation, the person meditating represents relaxation, the weightlifter indicates the exercise effect of walking or bicycling and the book indicates opportunities to read during carpooling. These icon sets and a series of images in the interface provide a personal awareness of green transportation activities and stimulate users' curiosity to discover the next image of the interface according to their levels of green transportation activities. The UbiGreen application also provides opportunities for engagement to take more activities. Deviating from the initial design concept, the users perceived the application as a real-life game that makes them become engaged in performing more green transportation activities. Also, the application

unexpectedly produced a social sharing element, serving as a communication trigger at users' homes and work places about their transportation activities. The results of the study showed a potential for behavior change as some users began to consider eco-friendly ways to save energy and participate in more green activities.

2.3.2.3. Health Domain

In the health domain, the Playful Bottle, MAHI, a smart kitchen for nutritional-aware cooking and waterbot are just a few examples of persuasive systems. The Playful Bottle (Chiu et al., 2009) is a mobile social persuasion system to motivate people to drink healthy quantities of water with two hydration games included in the system: the TreeGame and ForestGame. The TreeGame is a single-user game with automated computer reminders, while the ForestGame is a multi-user computer-mediated social game providing reminders from group members playing the game. Users of the system are basically automatically reminded to drink a certain amount of water regularly to feed a virtual tree in the game. When they drink a sufficient amount of water, the tree will grow well. Otherwise, a healthy tree would slowly transform into a withered one. In the ForestGame, users are able to see the levels of their own trees as well as others. They can not only compare and monitor tree levels and their water drinking habits, but also send hydration reminders to other members who do not intake sufficient water. This virtual group competition and cooperation functions as social persuasion to influence water-drinking habits. Whenever users of the system drink a bottle of water, motion-based drinking actions are detected with the mobile phone attached to the bottle. The results showed that the two persuasion strategies, system automated reminders in the TreeGame

and computer-mediated social reminders in the ForestGame, enhanced the amount and regularity of water intake more effectively than the system reminders alone.

MAHI (Mobile Access to Health Information) is a mobile health monitoring application that supports individuals with diabetes (Mamykina, Mynatt, Davidson, & Greenblatt, 2008). The MAHI framework consists of a conventional blood glucose meter, a Java-enabled mobile phone, a Bluetooth adapter to transfer data from the glucose meter to the phone, and a web application using PHP for asynchronous communication channels between users with diabetes and a diabetes educator. Individuals with diabetes use the MAHI to record their blood sugar levels and diabetes activities, and to share issues with diabetes educators. These features enable the users to utilize reflective thinking skills about their diabetes through social interactions with the educators. The results of the study demonstrated that the users of the MAHI showed relatively high acceptance rates, including engagement with the application and satisfaction with its use. The MAHI significantly helped users not only to obtain a perception of their role in diabetes management, but also to achieve actual management goals (change in diet). Namely, many of the users showed changes in their management habits from no meal pattern, no exercise and no monitoring of their diabetes levels to adopting stable diets and regular exercise, and frequent checking of blood sugar levels at least twice a day. More importantly, the MAHI played an important role in helping the users gradually adopt an internal locus of control that is considered to be a prerequisite element for continuous engagement in self-care as well as more sustained behavior changes.

Chen et al. (2010) presented a smart kitchen for nutrition-aware cooking with three prototypes that have been gradually improved to support making healthy, informed

decisions. It automatically senses the cooking activities of the users and provides real-time feedback of nutrition information so that the users are able to adopt healthy cooking styles. Although each prototype is different in its name and functions, they basically consist of two modules: a nutrition tracker and an awareness display. On a display that mirrors the physical kitchen's surface, the awareness display presents the nutrition information of the food ingredients, including the food item's calories, weight, composition, and position as obtained by the nutrition tracker. Whenever a user performs a cooking action, such as adding, cutting or removing ingredients, the display updates the nutrition information of the ingredients. The first prototype, the Nutritional Facts Display, had these basic features and enabled the user to get real-time awareness of detailed nutrition information in order to adjust the amount of the ingredients. However, the user interview revealed that the information in the first prototype was overwhelming and only showed information about the recent ingredients without showing the overall aggregated number. In the second prototype, the Calorie Display, the improvements included (1) presenting only calorie information, which is the most contextually relevant information to the user to prevent information overload; (2) utilizing size-mapping and color-coding to quickly identify containers and distinguish low and high calorie ingredients; and (3) using a budget metaphor to recognize the difference between current and desired calories. The result of the second study showed that the users were able to adapt the Calorie Display to accurately measure the proper amount of ingredients and make informed decisions about healthy cooking. Although one user failed to meet the desired calories due to personal preferences and cooking habits, other users made positive comments on the second prototype and showed their willingness to consider an appropriate amount of

calories in future shopping. The third prototype, the Calorie and Nutrition Balance Display, added the nutritional-balance information of the ingredients to four food groups: grains, vegetables, meat and beans, and oils. Therefore, the display interface showed the current and recommended calories of both the food ingredients overall and the individual ingredients in each food group. The results demonstrated that the users were able to meet the recommended calorie budgets for each food group, achieve nutritional balance and choose alternative ingredients.

Arroyo, Bonanni and Selker (2005) presented four parallel prototypical interfaces in the sink to improve safety, hygiene and conservation of water and, ultimately, encourage behavior changes. The first prototype, HeatSink, was designed to provide useful information on the temperature of the water without altering the sink function. It had a colored LED mounted around the faucet aerator that illuminated the stream of water. Red colored light meant that it was hot, while blue colored light meant that it was cold. In this way, the users were able to recognize the temperature of water without directly touching it. The second prototype, SeeSink, was an interface that combined the automation principle and context-aware sensing and actuation to interpret a variety of user tasks and to provide appropriate hands-free control of the water temperature and flow. The initial design concept was used to overcome the innate limitation of automated faucets, which only automatically turn the water flow on and off. They did not control temperature or amount of water flow. To this end, the SeeSink contained a CCD camera mounted on the faucet that interpreted a variety of user tasks and provided the appropriate water flow and temperature automatically. For example, the SeeSink dispensed cold water when vegetables were recognized and warm water when a user presented his or her

hands. The third prototype was the CleanSink, which was designed to critically encourage behavior changes so that people would wash their hands at special places where hand-washing compliance is necessary, such as hospitals, restaurants and industrial clean rooms. In a medical examination room, the CleanSink controls the light of the room, which is only brightened once a user washes his or her hands. In an industrial clean room, the CleanSink has control over the electronic door lock so that it is opened once a user washes his or her hands. The last prototype, WaterBot, utilizes the principles of adaptive interfaces, positive reinforcement, just-in-time prompts and social validation to motivate people to conserve water. When a user closes the tap while using the sink, it presents positive visual and auditory feedback (positive message and chimes with random color illuminations on two bar graphs) as a reward. It tracks water usage and savings of the user and shows a comparison to the usage of others users, which functions as a social validation element. The results of the evaluation study demonstrated that users intuitively understood the visual and auditory forms of, and were engaged and accustomed to saving water even after a two-month evaluation period.

2.3.2.4. Physical Activity in the Health Domain

A variety of persuasive technologies have been proposed to encourage users to complete more regular physical activities. The most popular ones are the Active Video Games (AVGs), such as Dance Dance Revolution (DDR), Nintendo Wii Fit games and Microsoft Kinect games, which have been developed to encourage physical activity, while decreasing sedentary activity by leveraging the advantages of video games, such as enjoyment, sustained attention and interactions with players (Straker et al., 2009; Graf et

al., 2009; Leatherdale et al., 2009; Foley et al., 2010; Biddiss & Irwin, 2010). "Escape from Diab" (Diab) and "Nanoswarm: Invasion from Inner Space" (Nanoswarm) were specifically designed to lower the risks of type 2 diabetes and obesity by changing youths' diets and physical behaviors (Barnet, Cerin, & Baranowski, 2011). HealthSeeker, developed by the Ayogo game consulting company in collaboration with Joslin Diabetes Center, is a social game on Facebook designed to encourage game players with diabetes by giving small awards in the form of virtual game money, when they make small lifestyle changes (Kamal, Fels, Blackstock, & Ho, 2011). Several studies on the effectiveness of the AVG have demonstrated that energy expenditures were significantly higher during AVG play when compared to inactive gaming or being at rest (Leatherdal, Woodruff, & Manske, 2010; Graf et al., 2009; Lanningham-Foster et al., 2009).

The Activator (Romero, Sturm, Bekker, Valk, & Kruitwagen, 2010) is one of the persuasive technology concepts aimed at motivating elderly residents of a care facility to be aware of and encourage them to participate more in physical and social activities. It uses the persuasive elements of playfulness, curiosity, nurturing, exploration, self-monitoring and socialization as mutual motivators in their interactive leaflet-shaped visualizations. The activities are sent to the older adults in a representation of flickering leaflets about current and upcoming events. Then, the older adults are able to flexibly choose whether to physically and socially engage in certain activities.

Mobile phones have been widely accepted as a major persuasion platform (Fogg & Eckles, 2007) that can be used to change sedentary lifestyles to more active lifestyles and persuade users to exercise regularly because they are ubiquitous and almost always with the users. Houston (Consolvo, Everitt, Smith, & Landay, 2006) is a mobile fitness

journal software that can be ported to a mobile phone so that it can communicate with a user's pedometer in order to record the user's steps so that they can view their activities, set goals and share information with others. Shakra (Anderson et al., 2007) is also a mobile activity tracker developed to motivate fitness and health. It provides users with the ability to view their fitness activities and sharing the data with others. The difference between Houston and Shakra is that Shakra uses fluctuation in GSM signals and neighboring cell information so that the users do not need to equip a pedometer to enter their activities. The Nuadu toolbox is a set of applications and services that use mobile devices for personal health management (Mattila et al., 2008) in order to providing assessments of users' physical activities. Users enter the exercise information they performed, such as self-assessed intensity, distance and training effect as obtained from a heart rate monitor. The Nuadu toolbox quantitatively analyzes the effectiveness of their exercises based on these data and provides both an analyses of a user's goals as well as suggestions on how to achieve the goals. By using the tool, thr users in the experiments were significantly more likely to meet their goals of increasing physical activities and the effectiveness of their energy expenditures (Consolvo et al., 2006; Anderson et al., 2007; Ahtinen et al., 2009). Nelson, Megens and Peeters (2012) designed Bouncers, a live wallpaper for Android smartphones, to visualize the physical activities of team members. Team members are visualized as circles on the phone's wallpaper and their activities are represented by the speeds of the circles, calculated by an accelerometer on the smartphones. The results of the four-week study showed that the 30 users thought that even though Bouncers was initially designed as a platform to provide shared insights on the activities of the team members in abstract and subtle ways, it unintentionally created a

social context of stimulating intrinsic motivation. Therefore, it resulted in increased feelings of social connectedness among the members of the group and an increase in social activity. However, the effectiveness of the group factor as a persuasive element that depended upon the closeness of the group members and was not investigated in the long-term.

However, in spite of these efforts and developments, there are criticisms. The first criticism focuses on the relationship between sedentary behavior and physical behavior. On the one hand, several researchers have argued that sedentary behaviors, such as TV viewing and playing video games, are influential determinants for juvenile physical inactivity and obesity (Falciglia & Gussow, 1980; Gortmaker et al., 1996; Steinbeck, 2001) and that decreasing sedentary behavior, while increasing activity are important factors in treating youth obesity (Epstein et al., 1995). On the other hand, other researchers have argued that sedentary behaviors are not largely correlated with physical activity, suggesting that youth have time for both sedentary and physical behaviors. There is no significant difference in the time spent on sedentary activities today compared to children 40 years ago (Biddle et al., 2004). Several longitudinal studies have also failed to demonstrate a significant relationship among low energy expenditure, youth obesity and physical inactivity (Ekelund et al., 2002; Johnson et al., 2000; Salbe et al., 2002).

The second criticism focuses on the effectiveness of the tools in the long-term. For instance, although the participants in the experiments with Houston, Shakra and the Nuadu toolbox provided positive feedback about the effectiveness of their energy expenditures, the durations of the experiments - around 2 weeks - were too short to show longer and sustainable effects of the tools on behavior changes. Also, no empirical

evidence exists about the factors making the participants participate in physical actions regularly, such as going to the gym. Children's use of the DDR game decreased with time. Only two children out of 21 (9.5%) had sustained use of the DDR twice a week or more (Madsen et al., 2007, as cited in Biddis & Irwin, 2010). The frequency of AVG play and its efficacy in the long-term remain unknown in spite of its effectiveness of energy expenditures in the short-term (Biddis & Irwin, 2010).

The other criticism focuses on the dietary effectiveness of playing video games to increase physical activity and is due to low energy expenditures. Although the energy consumed during the game playing activity was significantly higher than playing sedentary video games or remaining sedentary, it was not high enough to reach the recommended daily amount of calories required for children to lose weight (Graves, Stratton, Ridgers, & Cable, 2007).

2.3.3. Summary of Persuasive Technologies

As presented above, the examples of the persuasive systems in the four most significant domains have applied several persuasive strategies and design principles. Although these systems effectively influenced people's behaviors and attitudes to some degree, limitations still exist, as shown in the literature, including dietary effectiveness and sustainable persuasive effectiveness in the long-term and real world settings (outside controlled experimental settings). In the next chapter, the details of the main study about behavioral changes are discussed, including how the persuasive elements were included, how the solutions were designed to overcome the limitations and how those solutions were empirically tested.

CHAPTER 3: BEHAVIOR CHANGE STUDY

This chapter presents (1) the purpose of the HamkeRun study for this dissertation, (2) the hypotheses used to test the effects of the persuasive motivational elements and whether these elements resulted in increased motivation and increases in the number of running activities, (3) the HamkeRun application to present how the persuasive motivational elements were chosen and developed and (4) the experimental design to empirically test the hypotheses and demonstrate the motivational effect of the HamkeRun application.

3.1. Purposes

There are three main purposes for the HamkeRun study. The first purpose was to develop a theoretical framework that explains cognitive and motivational models in stages of behavior change when people receive persuasive elements for incremental and sustainable behavior change. The next main purpose was to design, develop and test a persuasive application that combines motivational elements in order to increase the motivation of users to run more frequently. The final main purpose was to provide design guidelines for application designers and developers, not just in the running domain, but also in the health-related domain where behavior change is needed.

3.1.1. Purpose #1: Develop a Theoretical framework

The first main purpose was to develop a theoretical framework that explains cognitive and motivational models across multiple stages of behavior change when runners are exposed to persuasive elements for incremental and sustainable behavior change, not just in the short term, but also in the long term. Most studies explaining cognitive and motivational models of behavioral change in the contexts of exercise and running are from theories in psychology, sports management and health, not from HCI. In addition, even though several studies in HCI describe persuasive technologies that elicit the behavioral change of system users, few studies exist that focus on the relationship between motivational elements in persuasive technologies and different stages of behavior changes, especially in the running domain.

After reviewing the literature on motivation and behavior changes, a combination of the transtheoretical model's stages of change (Prochaska & DiClemente, 1983) and the FBM (Fogg Behavior Model; Fogg, 2009) were determined to be the best fit for this research because, together, these theories can explain the participants' motivational changes in each stage of behavior change when different persuasive motivational elements are provided. By combining these models, these initial questions emerged:

- What persuasive elements provided in the tool will increase the motivation of runners who are at different stages of behavior change to run more frequently?
- Would it be possible to increase the extrinsic motivation of runners in the maintenance stage by using the persuasive elements?

A study of the transtheoretical model in the exercise domain (Prochaska & Marcus, 1994) showed that if the user in the precontemplation phase had more extrinsic motives (e.g., appearance, weight management), the less intrinsic motivations (e.g., enjoyment, revitalization) would dominate. However, this dominance of extrinsic motives over intrinsic motives is weakened in the contemplation phase. Indeed, the dominance of the extrinsic motives disappears; that is, they are similar to each other in the preparation phase. Surprisingly, extrinsic motives dominate intrinsic motives again in the action phase. However, this dominance is reversed in the final, maintenance phase. These results suggest that extrinsic motives dominate during the early stages of exercise adoption, while intrinsic motives play an important role in the progression to and maintenance of the actual activity.

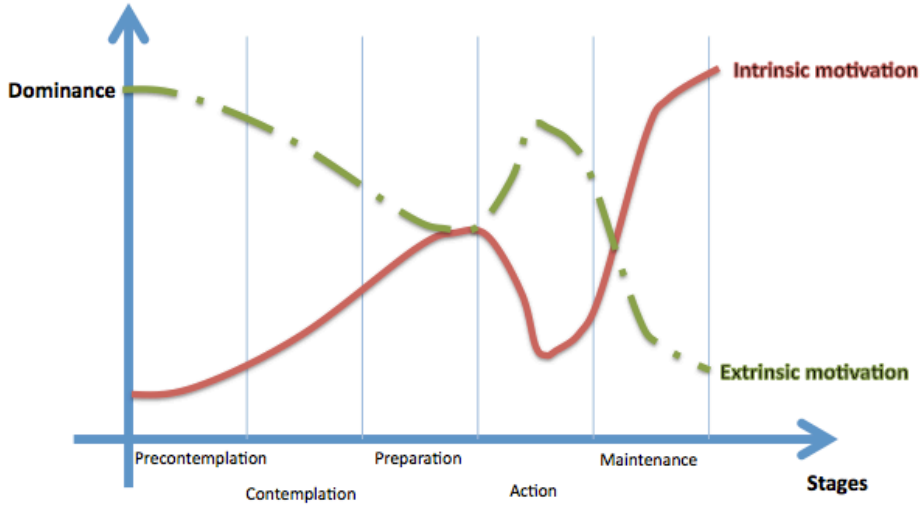

Figure 5. Motivational dominance in each stage of behavior changes in the TTM (Prochaska & Marcus, 1994)

Figure 5 shows the motivational dominance of both the extrinsic and intrinsic motives in each stage of the behavior changes. The dotted line is the extrinsic motivation, which indicates that it dominates the early stages, and the solid line is the intrinsic motivation, which shows dominance in the later stage. As shown in Figure 5, the dominance of extrinsic motivation significantly drops in the maintenance stage, while intrinsic motivation is significantly escalated.

It is likely that a persuasive system, which provides users with motivation elements, will lead to intentional increase in extrinsic motivation even for runners at the maintenance stage (Figure 6). Therefore, the transtheoretical model explains the cognitive and motivational changes when a persuasive system provides users with motivational elements.

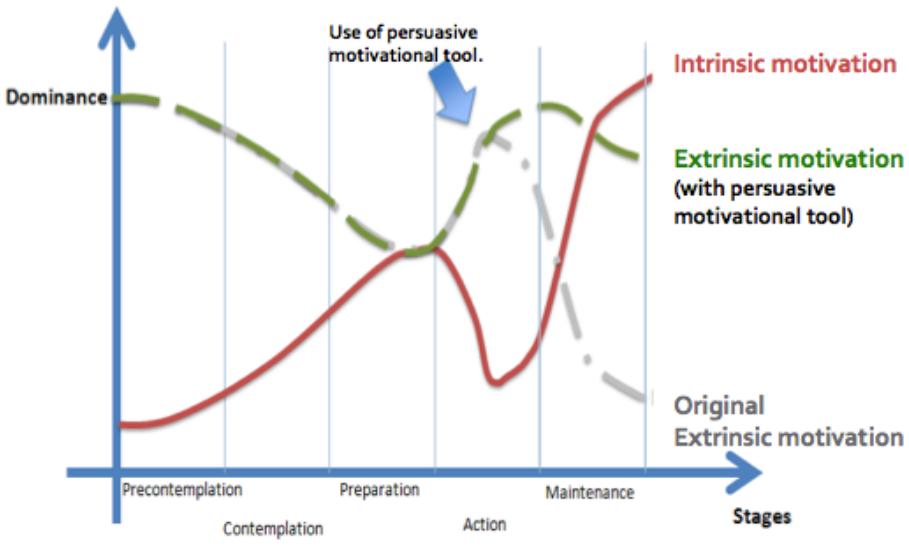

Figure 6. Expected motivational dominance in the transtheoretical model after using persuasive motivational tool

FBM (Fogg, 2009) states that behavior is a product of three components: ability, motivation and trigger. The requirements for an individual to perform a target behavior are that each factor must occur simultaneously and must be sufficiently strong. The FBM is used to identify the external factors that facilitate users to perform running activities or stop performing. These features are based on the assumptions that users' motivations will be intentionally increased by a persuasive system when the 'ability' factor is excluded because the participants in this study were only required to run or walk, meaning that no special abilities were required. Additionally, with the exclusion of the 'ability' factor, the FBM model was used to provide a more detailed consideration of a relationship between the different levels of motivation and the trigger, such as how different triggers influence runners at different stages of behavior change, what types of triggers runners at different stages of behavior change want to receive and what strength a trigger should be to effectively lead to an actual running activity being performed.

3.1.2. Purpose #2: Develop a Persuasive System for a Sustainable Behavior Change

The next purpose was to design, develop and empirically test a persuasive application, called HamkeRun. This application was designed for the purpose of increasing users' motivations to run more frequently. The HamkeRun application embeds three persuasive motivational factors: information visualization, gamification and social elements (Figure 7).

For the first motivational element, the HamkeRun application embeds information visualization, which can be defined as "the process of transforming data, information and

knowledge into [a] visual form making use of humans' natural visual capabilities" or more concisely, as "the computer-assisted use of visual processing to gain understanding" (Chittaro, 2001, p. 82). Early information visualization tools generated "static" images to find out desired outcomes due to low computing power and no interactivity (Lee et al., 2006). However, with technological advancements, these tools have evolved to provide more dynamic information, more interactivity and faster and more accurate outcomes. Many researchers have claimed that information visualization tools can provide ways by which to improve efficiency, reduce costs, gain new insights about data and information, recognize patterns in the data and increase user satisfaction (Chittaro, 2001; Lee et al., 2006; Lurie & Mason, 2007; Yi, 2008; Pfaff et al., 2010).

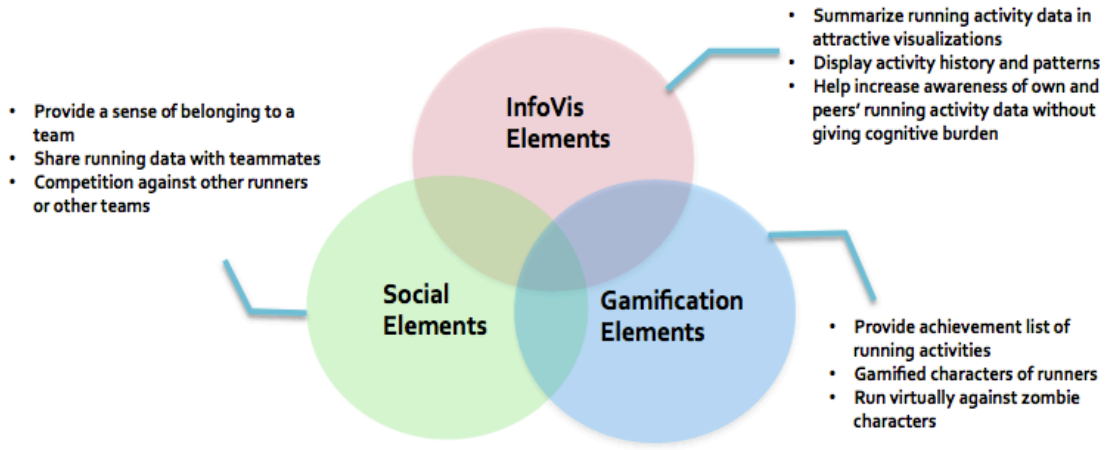

Figure 7. Persuasive motivational elements in the HamkeRun application

In addition, information visualizations can serve as aids for users to complete tasks by reducing the cognitive load needed to examine and understand the information provided. Simply, visual forms of information change humans' effortful cognitive tasks to perceptual tasks. For example, a bar chart can summarize a large dataset in a visual

form so that users can recognize overall trends quickly in a frequency distribution. In addition, a treemap provides both an overview and detailed information by displaying hierarchical data using nested rectangles (Plaisant, 2004). Therefore, the nature of the task is changed from identification and understanding of the data to comparison of the visualizations. Various information visualization tools have been developed and widely used in such fields as medicine, business and education (Heer, Bostock, & Ogievetsky, 2010).

Next, the HamkeRun application embeds gamification as a second persuasive motivational factor. Gamification can be described as a persuasive method to include game-like features in non-gaming applications, such as finance, health, news and education. This method has been applied in order to provide improved user experience, playfulness and user engagement (Deterding et al., 2011). Example components include a scoring system (e.g., ranks, levels and scores), a reward system (e.g., virtual badges), compelling narratives and competition (Antin & Churchill, 2011; Reeves & Read, 2009). Therefore, the HamkeRun application provides several gamification elements used to provide users with enjoyment and positive feelings of achievement, while making them more engaged in their running activities

Finally, social elements were embedded as a third persuasive factor in the HamkeRun application in order to increase the users' motivations to run more regularly and more frequently. As various persuasive technologies and researches have proven, the concept of social grouping is one of the most effective persuasive factors, which frequently results in positive behavior change, such as the WattsUp (Foster, Lawson, Blythe & Cairns, 2010) and the UbiGreen (Froehlich et al., 2009).

3.1.3. Purpose #3: Provide Design Guidelines for Persuasive System Designers and Developers

The last purpose was to provide design guidelines that could be used to help designers and developers build effective persuasive systems. The guidelines were based on findings from previous research and the results from the empirical study used for this dissertation. These guidelines can be used to help build effective persuasive systems for users at different stages of behavior change, not just in the running domain, but also in health-related domains where behavior change can have a significant impact on.

3.2. Hypotheses

To achieve the main purposes described in the previous sections, the initial questions were classified into more detailed questions.

(1) To what extent does the gamification element have persuasive power for runners?

(2) To what extent does the social element have persuasive power for runners?

(3) Will these persuasive elements lead to behavior changes, including performing actual running activities, and not just increases in motivation levels?

(4) To what extent do these persuasive elements affect runners who are at different stages of behavior change? Will the persuasive elements still influence an increase in the motivation of the runners at the maintenance stage of behavior change?

(5) To what extent do these persuasive elements affect differently on different genders.

These questions lead to the following hypotheses to test:

H1: *Presence of social element will increase persuasive power*

- H1a: social element ➔ significant increase in the external motivation of single runners
- H1b: social element ➔ significant increase in the internal motivation of single runners
- H1c: social element ➔ significant increase in the satisfaction of single runners
- H1d: social element ➔ significant increase in the number of running activities completed by single runners
- H1e: social element ➔ significant increase in the external motivation of team runners
- H1f: social element ➔ significant increase in the internal motivation of team runners
- H1g: social element ➔ significant increase in satisfaction of team runners
- H1h: social element ➔ significant increase in the number of running activities completed by team runners

***H2**: Persuasive elements will affect runners at different stages differently*

- H2a: persuasive elements ➔ significant increase in the external motivation of runners at the maintenance stage
- H2b: persuasive elements ➔ significant increase in the internal motivation of runners at the maintenance stage
- H2c: persuasive elements ➔ significant increase in the satisfaction of runners at the maintenance stage
- H2d: persuasive elements ➔ significant increase in the number of running activities completed by runners at the maintenance stage
- H2e: persuasive elements ➔ significant increase in the external motivation of runners at the action stage
- H2f: persuasive elements ➔ significant increase in the internal motivation of runners at the action stage
- H2g: persuasive elements ➔ significant increase in the satisfaction of runners at the action stage
- H2h: persuasive elements ➔ significant increase in the number of running activities completed by runners at the action stage

***H3**: Presence of gamification element will increase persuasive power*

- H3a: gamification ➔ significant increase in the external motivation of runners
- H3b: gamification ➔ significant increase in the internal motivation of runners

- H3c: gamification ➔ significant increase in the satisfaction of runners
- H3d: gamification ➔ significant increase in the number of running activities completed by runners

H4: *Persuasive elements will affect male and female runners differentially.*

- H4a: persuasive elements ➔ significant increase in the external motivation of male runners
- H4b: persuasive elements ➔ significant increase in the internal motivation of male runners
- H4c: persuasive elements ➔ significant increase in the satisfaction of male runners
- H4d: persuasive elements ➔ significant increase in the number of running activities completed by male runners
- H4e: persuasive elements ➔ significant increase in the external motivation of female runners
- H4f: persuasive elements ➔ significant increase in the internal motivation of female runners
- H4g: persuasive elements ➔ significant increase in the satisfaction of female runners
- H4h: persuasive elements ➔ significant increase in the number of running activities completed by female runners

3.3. HamkeRun Mobile Application

To test these hypotheses, I designed and developed the HamkeRun application, which embeds the concepts of information visualization, gamification and social elements. It was developed as a mobile application mainly due to the pervasiveness of mobile phones in our daily lives and the emerging role of phones as a major persuasion platform (Fogg & Eckles, 2007). Below are the detailed rationales as to why the three main concepts were included as persuasive motivational elements in the study.

3.3.1. HCI / Information Visualization Elements in HamkeRun

Figure 8. HCI / Information visualization elements in the HamkeRun application

First, the HamkeRun application embeds information visualization elements about the running activities of the users (Figure 8). The reasons behind including the information visualization element were to (1) visually attract users to their activity data, (2) give users a broader and better understanding of their activities and (3) make users get absorbed in their visualized data. The HamkeRun application displays the users' running activity data, including the overall, current and previous activities shown in four categories: average speed, max speed, total distance and total calories burned. It also displays the summarized progress of other users in bar charts and line charts. These visualized graphs (charts) can be attractive enough to sustain the users' interests and intuitive enough to understand the running patterns quickly. These information visualization elements may enable users to compare their data to their own previous activities as well as to peers' activities in ways that minimize mental calculation. Therefore, users are expected to understand more of both their own data and that of their peers.

3.3.2. Gamification Elements in the HamkeRun Application

The HamkeRun application includes several gamification elements in order to provide an improved user experience, playfulness and user engagement. The elements include an overall game-like theme, iconized characters and achievement system. The overall game-like theme in the HamkeRun application is a running battle between heroes and zombies or among groups of heroes. In the application, the users are the heroes, while the zombies are the targets to beat at the running activities. The zombies are, in fact, a representation of the previous activities of the users. Restated, the users' running activities were transformed into the characterized form of zombies having the actual users'

previous data (Figure 9). For instance, a user ran yesterday for five minutes at an average speed of five mph. Each speed interval was stored at every minute. This stored activity data was then added to a virtual zombie character. Then, when the user chooses to run today against this zombie that has yesterday's activity data, the application provides the information with, every minute, information about who is running faster or who will finish first based on the user's current speed and the information used for the zombie. Zombies can represent the user's own activities as well as those activities of teammates or other unknown runners. The combination of this game-like theme and the iconized characters is intended to make the users become more engaged in the theme and the HamkeRun application and indirectly induce them to perform actual running activities.

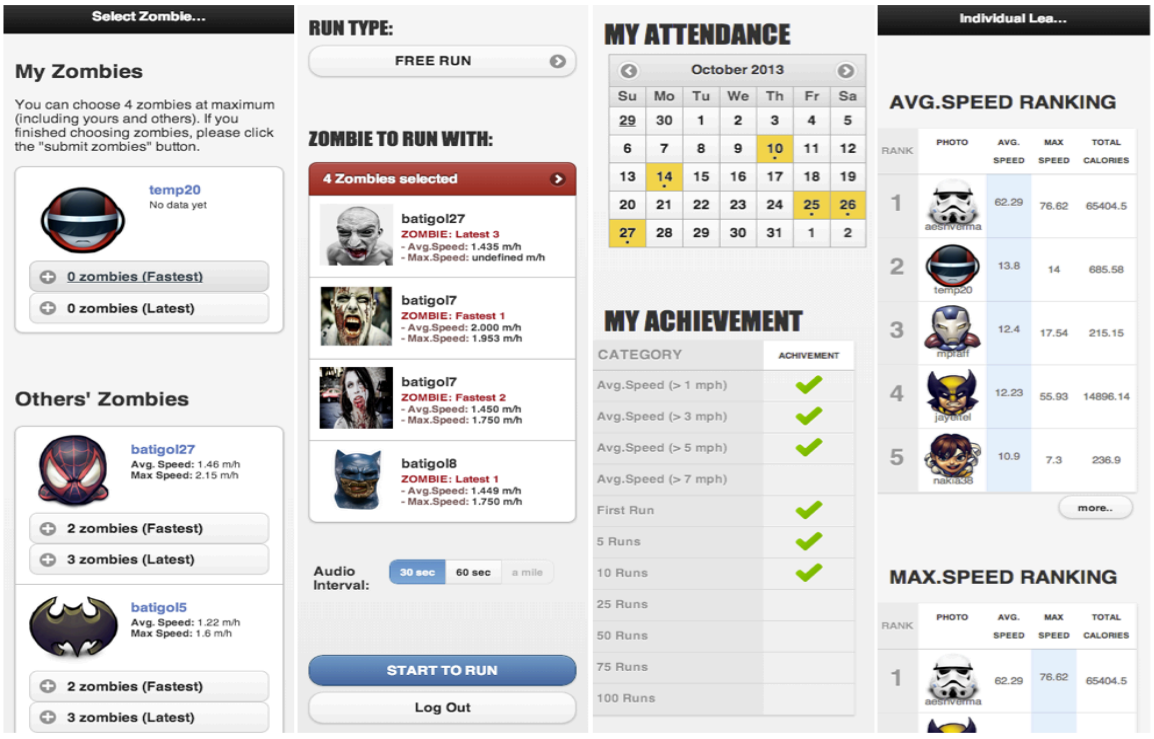

Figure 9. Gamification elements in the HamkeRun application

The next gamification element is the achievement system. As shown in the middle image of Figure 9, the achievement system is comprised of an achievement table ("My achievement") and an attendance calendar ("My attendance"). The achievement table shows a list of running missions completed and those missions still to be completed. When a user completes one mission, such as running faster than five mph or running five times, a green checkmark is added to the right side of the mission. Therefore, the user is able to intuitively understand and be motivated by what is achieved and what needs to be completed. The attendance table shows the dates that the user ran. The visual representations in the achievement table coupled with the attendance calendar serve as virtual badges for the completion of the users' activities.

3.3.3. Social Elements in the HamkeRun Application

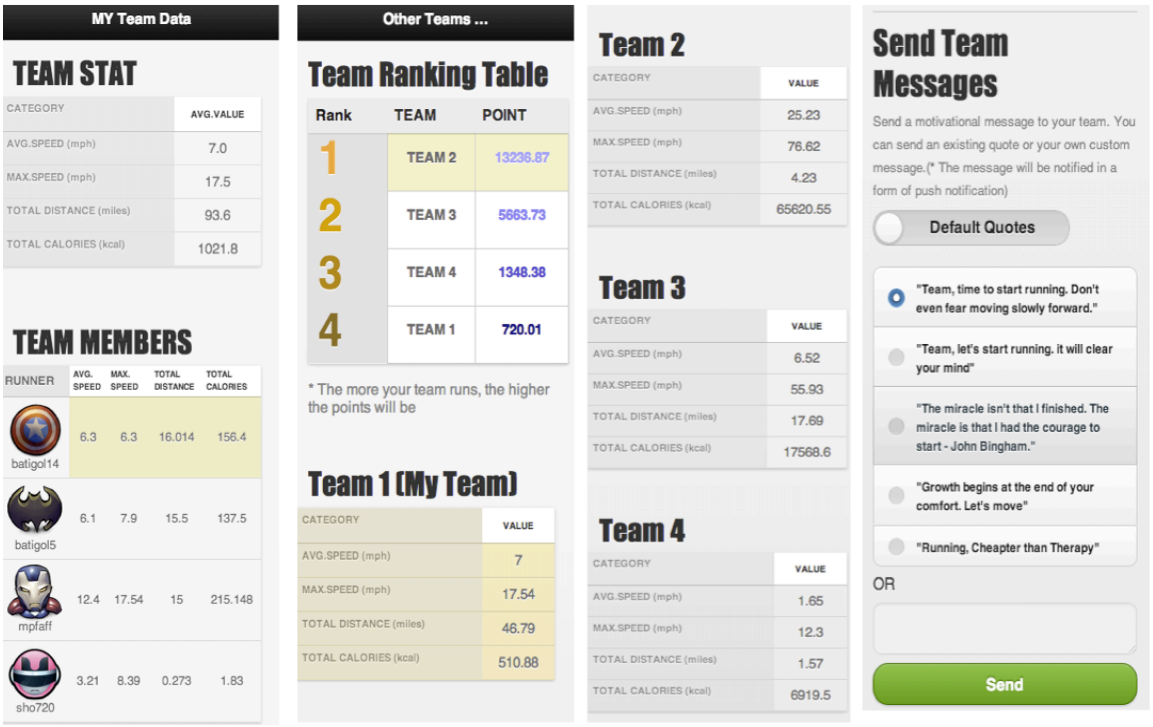

Figure 10. Social elements in the HamkeRun application

The social elements (Figure 10) are included in the HamkeRun in two forms: social cooperation and social competition. On the one hand, in a social cooperation setting, the users are able to not just run individually, but also run as a team member. Each team member shares his or her running data with teammates within the same team, not with members of other teams. The team members can view the shared data about their team, including overall team statistics and detailed running data for each team member across four categories: average speed, max speed, total distance and total calories burned. The social competition element in the application allows the team members to view other teams' overall statistics and compete with them virtually. The running activities of the team members are calculated and aggregated into running activity scores, which are the determinant of the team's rank among multiple teams. When team members think that they need more running activities to increase their running score, they are able to send motivational messages to team members by choosing from existing motivational quotes or by writing their own messages. In the application, these features of social support and social competition simultaneously function as persuasive elements to perform a running activity. Finally, the application shows the top performance runners among both known and unknown runners (right in the Figure 11). Therefore, the users are able to socially compete with other individuals and teams.

3.3.4. Modes in the HamkeRun application

Combining the persuasive elements, the HamkeRun application has two main modes: run mode and data mode.

(1) *Run mode*: A runner uses this mode when performing a running activity. In this mode, the runner is able to choose zombies as virtual running partners up to maximum of four. Each minute, the participant receives an auditory cue telling him or her who is running the fastest, what rank he or she is currently at and who will finish the running activity at what time. When the participants click the "stop activity" button, the application shows the run results table, which summarizes the running activities of the participants (upper left in the Figure 10) and the run comparison table, which summarizes the running activities of the participant and the chosen zombies (bottom-left in the Figure 11). The results data about the participant's running activity are sent to and stored on the server. For better user experience, the participant only needs to click twice (clicking the start activity button when they start a running activity and clicking the stop activity button when they want to finish the activity).

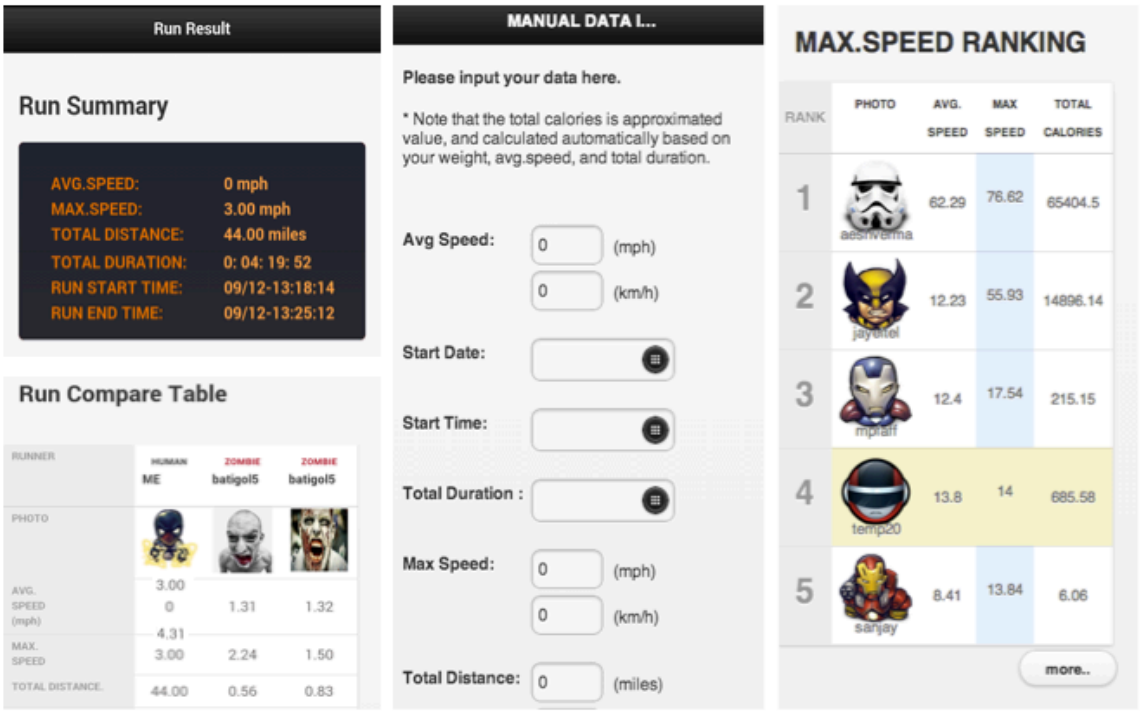

Figure 11. A screenshot of run summary (left), manual data entry (center), and leaderboards (right)

Sometimes, the participant cannot produce data or produces lots of noisy data due to unknown, intended or unintended reasons, such as a loss of the GPS signal, running without bringing a mobile phone, running on a treadmill at a gym or running using a GPS watch. To overcome these situations, the HamkeRun application allows the participant to enter their activity data manually, but only if he or she knows his or her average speed and duration (right in Figure 11). Other values including total distance and total calories burned, which are calculated automatically according to the participant's weight and internal calories equation. This information is then stored on the server.

(2) *Data mode*: The data mode is designed to display the individual data of the participant, team data and leaderboard data. On the individual running activity page, the application displays the participant's overall statistics of his entire running activities, the statistics from his latest activity, the attendance calendar, the achievement table and the information visualizations of his performance in the four categories (average speed, max speed, total distance and total calories burned). The team data page displays the overall team data statistics, detailed running activity data of each team member, the attendance calendar for each team member's, a list of messages that the team members have sent to each other to motivate them to run more actively and increase the team scores, and the team ranking table. The leaderboard page shows the ranking tables of all of the participants in the four categories, and the top performance runners (i.e., who is the fastest and who runs the most frequently).

3.3.5. Implementation

The HamkeRun mobile application was implemented using the Phonegap framework (http://phonegap.com), a free and open source framework that allowed me to create a mobile application using standard web APIs, including HTML5, JavaScript, CSS, and jQuery mobile (http://jquerymobile.com/). Another advantage of this framework is that one single block of code written using standard web APIs can be easily and quickly converted into various platforms, such as iOS, Android, Windows Phone and Blackberry. Therefore, the developer can minimize production time, while maximizing productivity and efficiency. On the backend, the Kinvey BaaS (Backend as a Service; http://kinvey.com) was used to store the collected data from the mobile device due to its simplicity in the development cycle for mobile applications.

3.4. Experiment

3.4.1. Experimental Design

In order to test the given hypotheses, an experiment using a 2×2 between subjects factorial design was selected to explore the persuasive effects of different levels of social elements and gamification. There were two independent variables, each of which had two levels, that were used to produce four distinct conditions: social element with gamification, social element without gamification, no social element with gamification and no social element without gamification (Table 5).

Table 5. 2 x 2 between subjects factorial design in the HamkeRun study

	Gamification (YG)	**No gamification (NG)**
Social element (S)	Condition1 (SYG): Social element + Gamification	Condition 2 (SNG): Social element + No gamification
No Social element (NS)	Condition 3 (NSYG): No social element + Gamification	Condition 4 (NSNG): No social element + No gamification

3.4.2. Participants

In the experiment, 52 participants were recruited from Indiana University campuses (Bloomington and Indianapolis, IN) and from local runners groups in Indianapolis, IN. Half of the participants (N=26) were at the action stage of behavior change, while the other half were at the maintenance stage. The criterion on the classification of the stages of behavior change between action and maintenance was whether the participants had habits of running for longer than six months (Prochaska & DiClemente, 1983). Twenty-nine of the participants (56%) were male and the remaining twenty-three participants (44%) were female. In the results of the demographic information questionnaire, 28 of the participants (54%) answered that their durations of their running activity (on average) were between a half hour and one hour. Thirteen participants (25%) answered 'less than a half hour' and 11 participants (21%) answered 'between one and two hours.' Regarding the number of running activities in a week, the most common response was 'twice a week' (33% by 17 participants), followed by 'once a week' (27% by 14 participants) and '3 times a week' (23% by 12 participants). More details about the demographics are included in Table 17 in the Appendix.

The participants were recruited through flyers, email and word of mouth. The proportions of gender and running experience were balanced, while other characteristics, such as age and race, were not controlled.

3.4.3. Independent Variables (IV)

(1) *Level of team engagement (Social element)*: The first independent variable was the level of the participants' engagement on a team. This variable was used to test the persuasive power of the social elements, namely whether team engagement would result in increased motivation to run more, a higher level of satisfaction and a higher frequency of completing running activities. There were two levels of team engagement: a single runner and a team runner.

(2) *Gamification*: The second independent variable was the existence of the gamification elements. This variable was used to test the gamification element in regard to whether it resulted in higher motivation levels to run more, a higher level of satisfaction and a higher frequency of completing running activities. Half of the participants in each group (single runner group and team runner group) received the gamification feature, while the other half of the participants did not.

3.4.4. Dependent Variables (DV)

(1) *Level of external motivation*: This variable was used to determine how much the persuasive elements in the HamkeRun application motivated people to run more and was measured at the end of each month.

(2) *Level of internal motivation*: This variable was the participants' perceived motivation level to run more, which was motivated internally, and was measured before the experiment and at the end of each month of treatment.

(3) *Level of satisfaction*: This variable was the participants' perceived satisfaction level about their running activity data and the application itself. This variable is measured before the experiment and at the end of each month of treatment.

(4) *Number of running activities*: This variable was considered to be the objective measure indicating the participants' frequency of performing the actual running activities.

Questionnaires are administered for subjective measures, including external motivation, internal motivation, satisfaction and number of running activities performed. The questionnaires also included questions about external factors (not from the HamkeRun application) that enticed the participants to run when their motivation was decreased.

3.4.5. Procedures

(1) *Overall procedure*: Fifty-two participants took part in the study. They were randomly assigned to two groups: the first group contained 20 single runners and the second group contained 32 team runners. In the team condition, there were four teams of eight runners. In each group, half of the participants were given the gamification features, while the other half were not. The duration of the experiment was two months. Although six months is often used as the time frame in which that the maintenance stage of change occurs (Pinto et al., 2011; Marcus et al., 2000; Schwarzer et al., 2007), there is no empirical evidence supporting this particular time frame (Van Stralen et al., 2009) and

several other studies have employed different time frames (Kim, Hwang, & Yoo, 2004; Pinto et al., 2005).

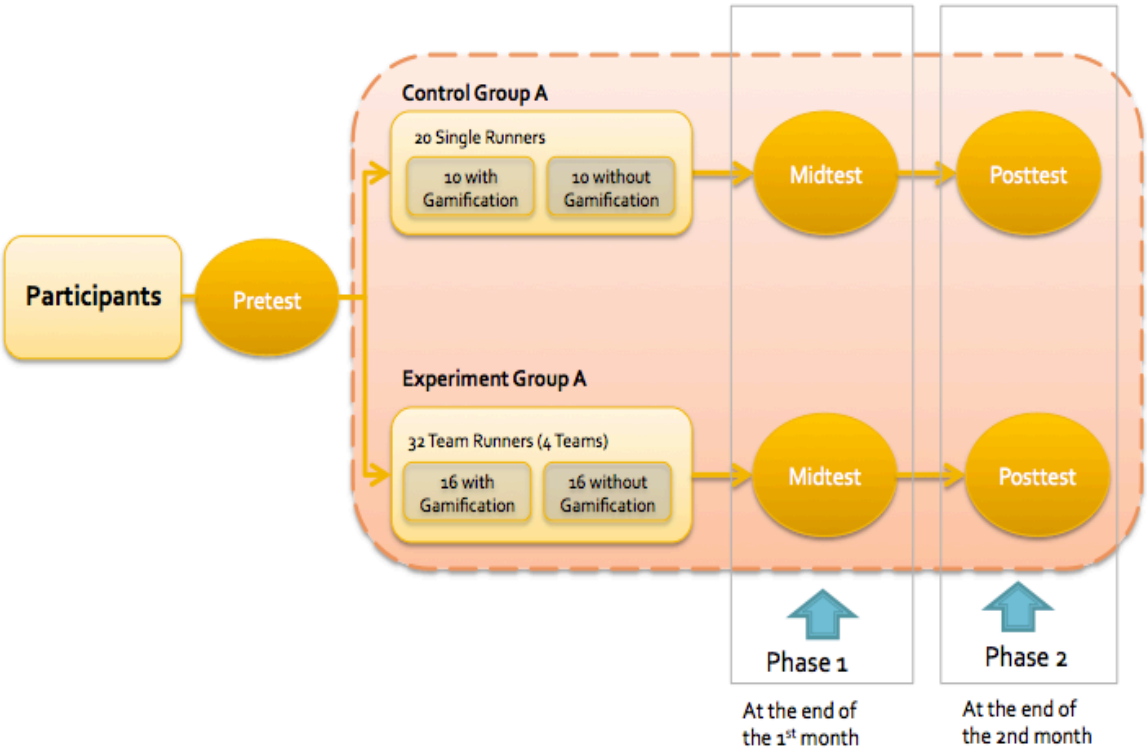

Figure 12. Experimental design of the HamkeRun behavior change study

The participants were asked to use the HamkeRun application for two months whenever they decided to perform a running activity. All of the activity performance data (average speed, max speed, total distance, total calories burned and attendance data) were automatically collected and displayed in information visualizations. The dependent variables were measured in the questionnaires, which were administered at the end of each month. There were a total of three questionnaires in the experiment: a pretest questionnaire before the experiment and two additional questionnaires, one at the end of each month.

(2) *Different flows per each condition*: Depending on the condition, there were four different flows of interactions that the participants could see in the HamkeRun application.

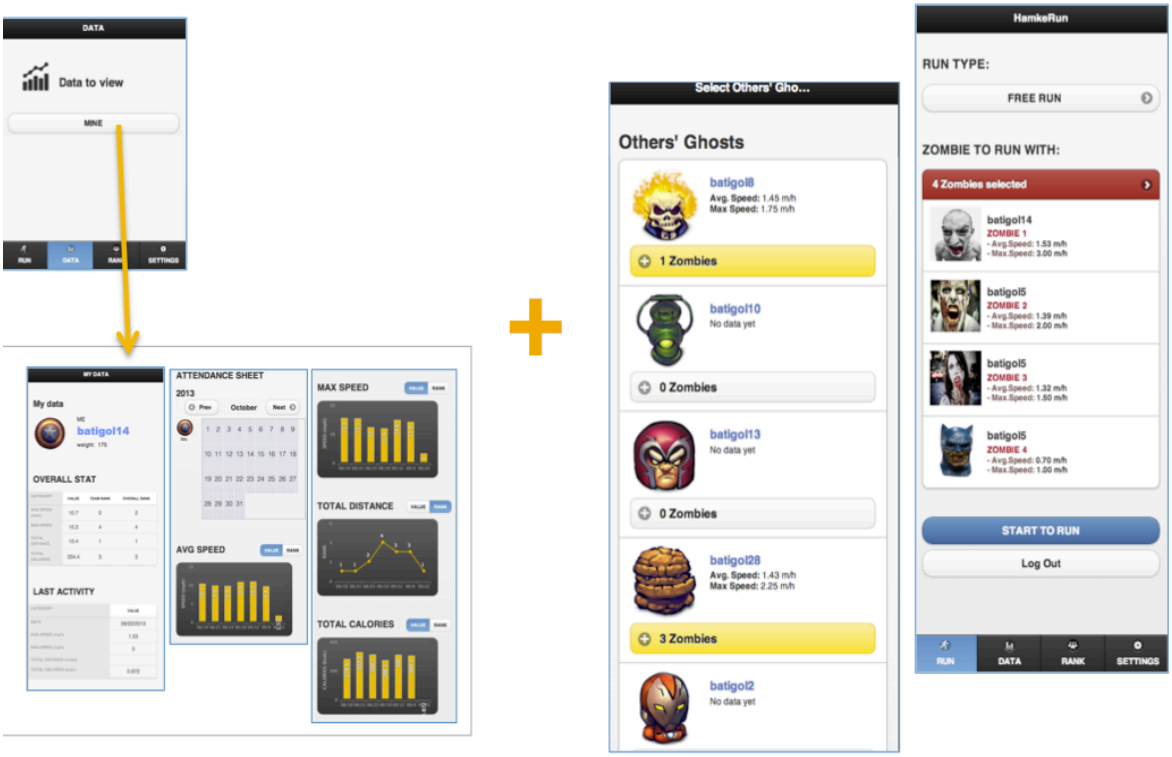

Figure 13. Flows for single runners with gamification (SRYG)

- Condition 1: **SRYG** (Social elements and Gamification): This condition was used for single runners (SR) with the gamification elements (YG). They could only see the individual running activity data, while all team related data was hidden and not accessible. However, the gamification elements, such as running with the zombies and the individual ranking table, were available (Figure 13).

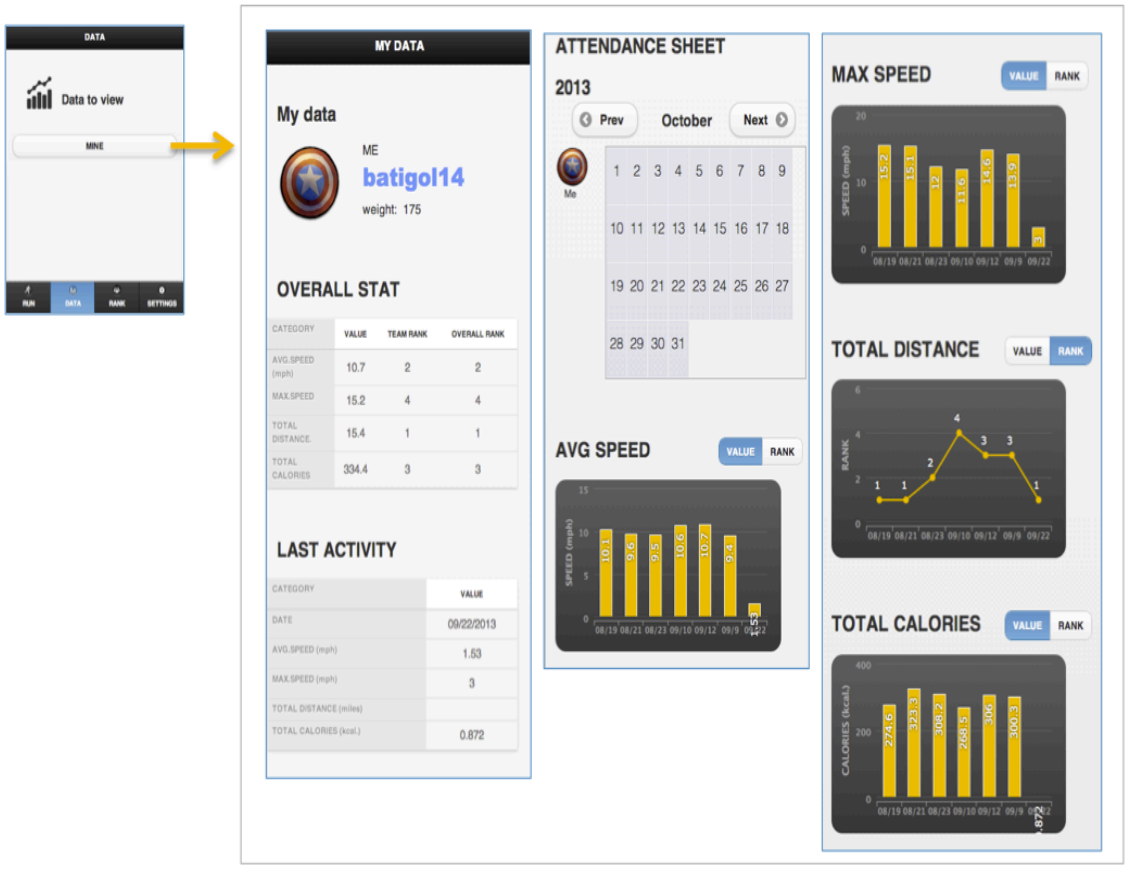

Figure 14. Flows for single runners without gamification (SRNG)

- Condition 2: **SRNG** (Social elements and No gamification): This condition was used for the single runners (SR) without the gamification elements (NG). They were only able to access the information visualization about their individual running data. Although they could use the run mode in the application, the zombie feature was not shown (Figure 14).

Figure 15. Flows for team runners with gamification (TRYG)

- Condition 3: **TRYG** (No social elements and Gamification): This condition was used for team runners (TR) with gamification (YG). They could access all of the features, including the individual data, team data, leaderboard data and zombie features (Figure 15).

Figure 16. Flows for team runners without gamification (TRNG)

- Condition 4: **TRNG** (No social elements and No gamification): This condition was used for team runners (TR) without gamification (NG). They could access all of the data, including the individual and team data as well as the leaderboard. However, the zombie feature was not visible (Figure 16).

CHAPTER 4: RESULTS

This chapter discusses the results of the data analysis and consists of the following eight sections: sample attrition, data analysis results on internal motivation (internal momentum for achieving a target behavior), external motivation (motivational effect of the HamkeRun application), satisfaction and number of running activities, total number of running activities, changes of the number of running activities, and satisfaction with the individual concepts of persuasive motivational elements.

4.1. Sample Attrition

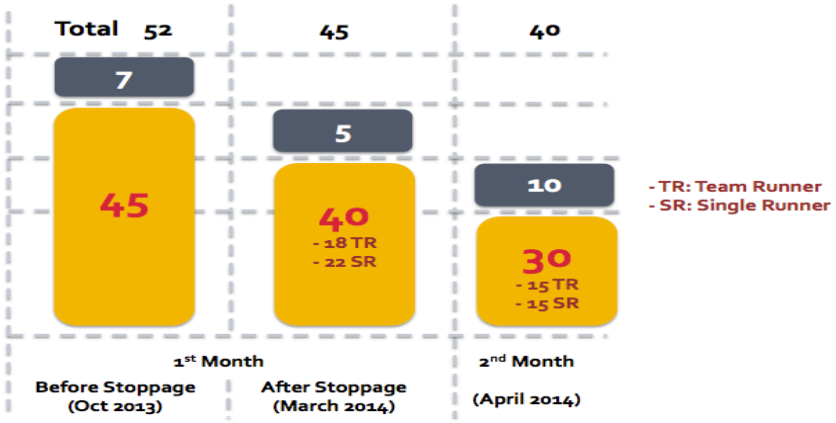

Figure 17. Sample attrition changes during the HamkeRun experiment

The HamkeRun study started in mid-October 2013. A total of 52 participants were recruited and joined the study in this month. However, due to unusually severe cold weather in Indiana (recorded as one of the top 10 coldest winters on record in parts of the Midwest, according to the National Oceanic and Atmospheric Administration (NOAA; Edman, 2014)), the study was postponed and resumed in March 2014. Due to this stoppage, 12 participants left the study during the first month (seven left before the

stoppage, while five left after the stoppage); thus, the remaining 40 participants completed the first month survey. During the second month, an additional 10 participants left the study, leaving a total 30 participants who completed the second month survey. The main reasons why the participants left the study are described in the first section of the next chapter. Figure 17 displays the details of the participants in each time point of the study.

4.2. External Motivation (EM)

External motivation was measured in order to determine how much the runners were motivated by the persuasive elements of the HamkeRun application. The measured data was collected through seven Likert scale-based questions (0: "Strongly Disagree" to 6: "Strongly Agree"). Due to the collected data type (ordinal scale) and small sample size, non-parametric Wilcoxon's signed rank tests were employed. Table 6 shows a summary of the test results on external motivation. The results were categorized using four between-subject factors: runner type, stage of behavior change, gamification and gender.

Table 6. Summary of non-parametric Wilcoxon's signed rank test results on external motivation from the first to the second month

Between subject factor	**Split by**	***N***	***z***	**Sig. Value**
Runner Type	**Single Runner**	**15**	**2.87**	**.004**
Runner Type	Team Runner	15	0.98	.325
Stage of Behavior Change	Action Stage	15	0.35	.723
Stage of Behavior Change	**Maintenance Stage**	**15**	**3.14**	**.002**
Gamification	**With Gamification**	**18**	**2.36**	**.019**
Gamification	Without Gamification	12	1.03	.304

Gender	**Male**	**19**	**2.37**	**.018**
Gender	Female	11	1.30	.192

4.2.1. External Motivation by Runner Type

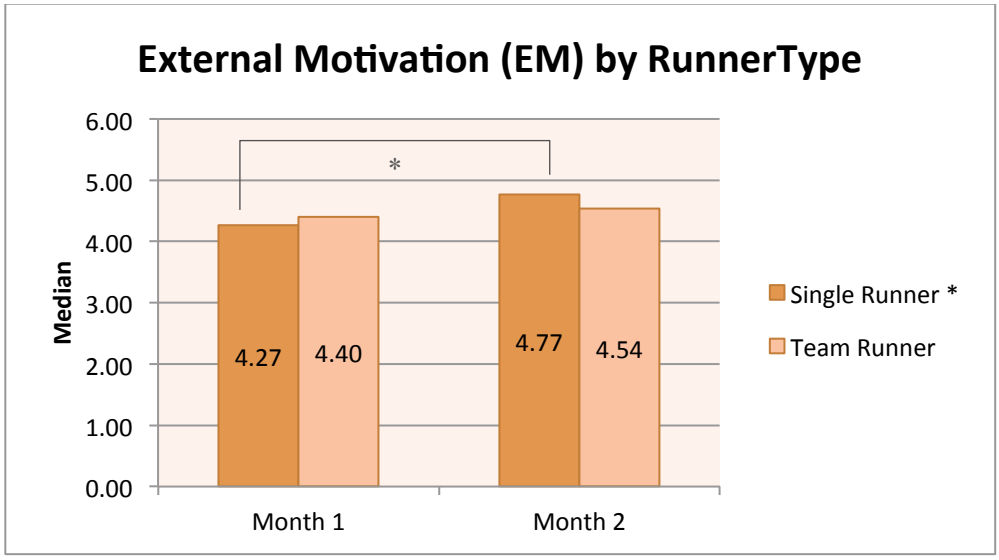

Figure 18. Median value changes of external motivation by runner type

Wilcoxon's signed rank tests revealed that the app's external motivation on single runners was significantly higher at the end of the second month (Mdn = 4.77) than at the end of the first month (Mdn = 4.27), $z = 2.87$, $p = .004$, $r = .52$. However, there was no significant increase of external motivation on the team runners from the first month (Mdn = 4.40) to the second month (Mdn = 4.54), $z = 0.98$, $p = .325$, $r = .18$. Thus, hypothesis H1a (social elements will significantly increase the external motivation of single runners) is supported, while hypothesis H1e (social elements will significantly increase the external motivation of team runners) is not supported. There was no significant difference between the single runners and team runners in the reported external motivation change scores (second month minus the first month), t (28) = 0.48, $p = .64$.

Table 7. A summary of 2 split non-parametric Wilcoxon's signed rank tests

	Split by		***N***	***z***	***Sig.***
Runner type x Stage of behavior change	Single Runner	Action Stage	7	1.27	.206
	Single Runner	**Maintenance Stage**	**8**	**2.52**	**.012**
	Team Runner	Action Stage	8	-0.74	.462
	Team Runner	Maintenance Stage	7	1.89	.058
Runner type x Gamification	**Single Runner**	**Gamification**	**9**	**2.24**	**.025**
	Single Runner	No Gamification	6	1.82	.068
	Team Runner	Gamification	9	1.36	.173
	Team Runner	No Gamification	6	-0.32	.750
Runner type x Gender	**Single Runner**	**Male**	**11**	**2.60**	**.009**
	Single Runner	Female	4	1.29	.197
	Team Runner	Male	8	0.51	.610
	Team Runner	Female	7	0.94	.345
Stage of behavior change x Gamification	Action Stage	Gamification	8	0.14	.893
	Action Stage	No Gamification	7	0.25	.799
	Maintenance Stage	**Gamification**	**10**	**2.67**	**.008**
	Maintenance Stage	No Gamification	5	1.36	.174
Stage of behavior change x Gender	Action Stage	Male	11	0.97	.331
	Action Stage	**Female**	**4**	**2.37**	**.018**
	Maintenance Stage	Male	8	-1.34	.180
	Maintenance Stage	**Female**	**7**	**2.03**	**.043**
Gamification x Gender	**Gamification**	**Male**	**11**	**2.43**	**.015**
	Gamification	Female	8	0.85	.398
	No Gamification	Male	7	1.21	.225
	No Gamification	Female	4	0.18	.854

In order to explore the potential differences in the subgroups that might have been obscured in the larger group analyses, additional two split Wilcoxon tests on external motivation were conducted in combinations among four between-subject factors: runner type, stage of behavior change, gamification and gender.

In the split by runner type and stage of behavior change, Wilcoxon's signed rank tests elicited that the app's external motivation on the single runners at the maintenance stage (SR + MS) significantly increased in the second month (Mdn = 4.83) when compared to the end of the first month (Mdn = 4.25), $z = 2.52$, $p = .049$. However, external motivation was not significantly higher or lower from the first month to the second month for single runners at the action stage or for team runners.

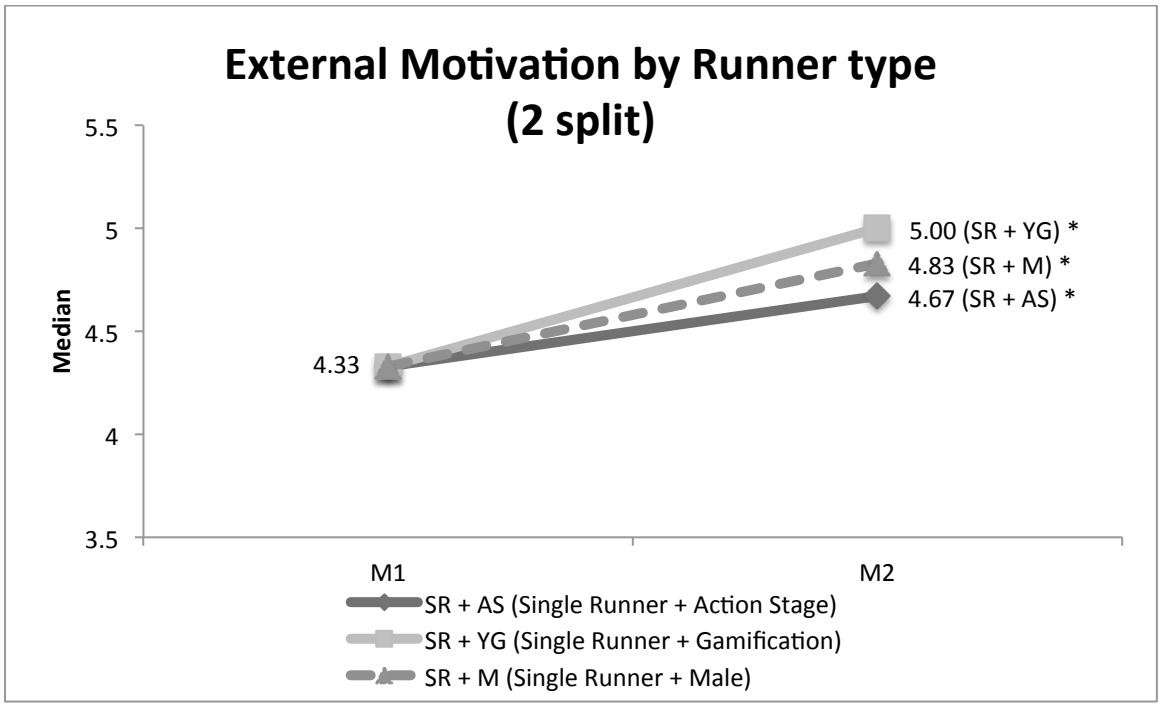

Figure 19. Split result of Wilcoxon signed rank test on external motivation by runner type

In addition, the Wilcoxon's signed rank tests for the split by runner type and gamification revealed that the app's external motivation on the single runners with gamification (SR + YG) was significantly higher in the second month (Mdn = 5.00) than in the first month (Mdn = 4.33), $z = 2.24$, $p = .025$. However, for single runners without gamification and for team runners, their changes in external motivation were not significant from the first month to the second month.

The results of the two split Friedman tests (split by runner type + gender) also revealed that the app's external motivation on the male single runners (SR+M) was significantly higher in the second month (Mdn = 4.83) than in the first month (Mdn = 4.33), $z = 2.60$, $p = .009$. However, the external motivation on the female single runners, as well as the male and female team runners did not show a significant increase or decrease from the first month to the second month.

4.2.2. External Motivation by Stage of Behavior Change

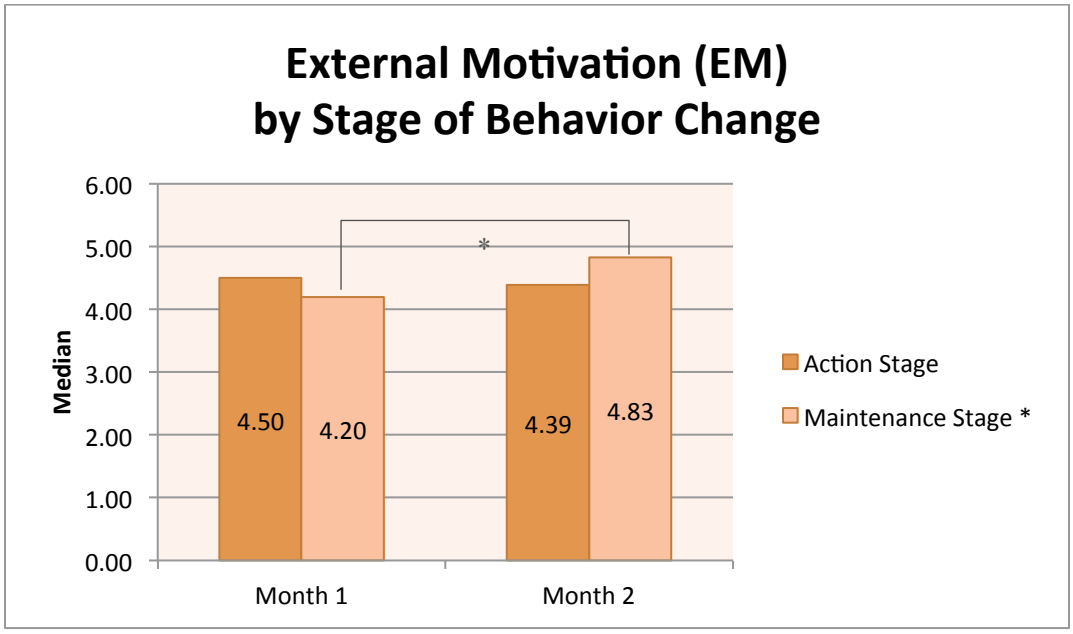

Figure 20. Median value changes of external motivation by stage of behavior change

A Wilcoxon signed rank test revealed that the app's external motivation on the runners at the maintenance stage was significantly higher in the second month (Mdn = 4.83) than in the first month (Mdn = 4.20), $z = 3.14$, $p = .002$, $r = .57$. However, the Wilcoxon signed rank test did not elicit a statistically significant change on the external motivation on the runners at the action stage from the first month (Mdn = 4.50) to the second month (Mdn = 4.39), $z = .35$, $p = .723$, $r = .06$. Thus, hypotheses H2a (persuasive elements will lead to a significant increase in the external motivation of runners at the maintenance stage) and H2e (persuasive elements will lead to a significant increase in the external motivation of runners at the action stage) were supported. A significant difference existed between the runners at the action stage and the runners at the maintenance stage in regard to the external motivation change score (second month minus first month), t (28) = -2.68, $p = .012$.

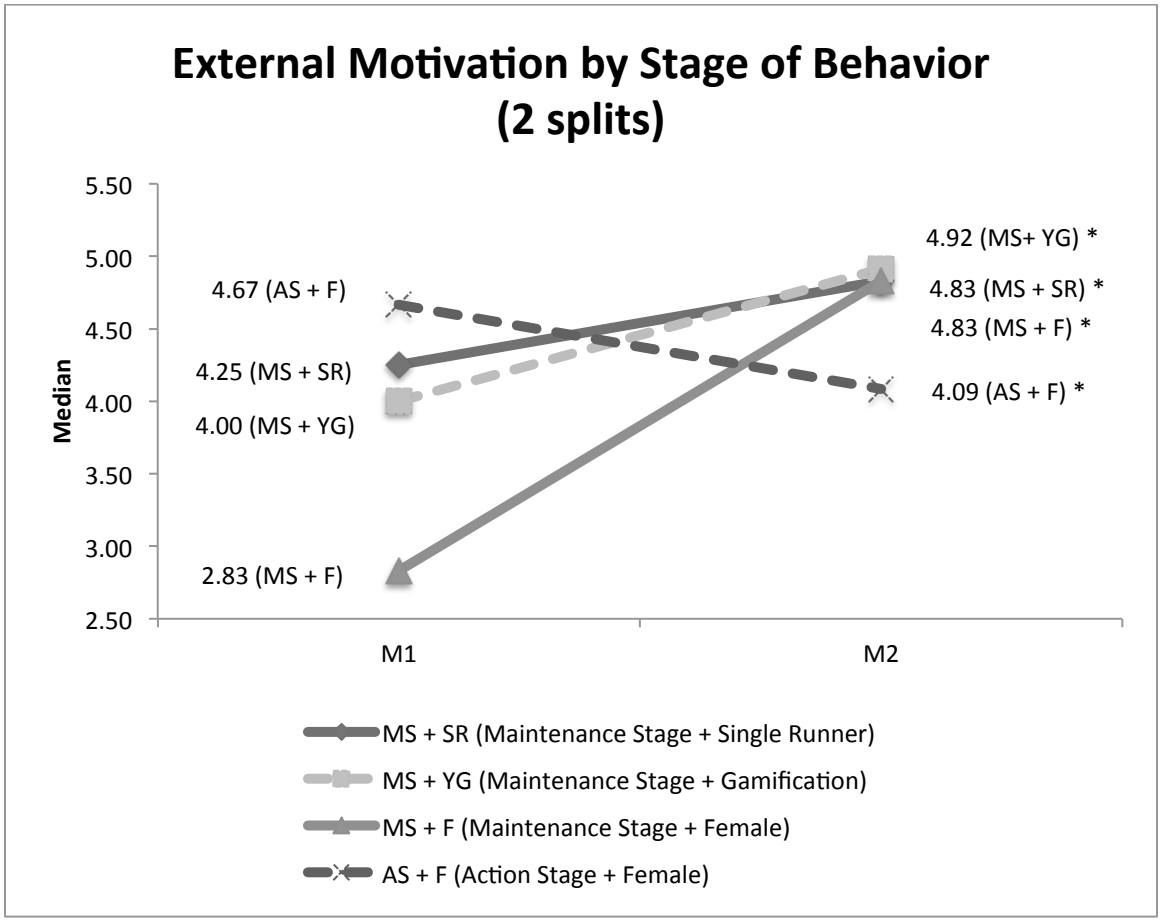

Figure 21. Split result of Wilcoxon signed rank test on external motivation by stage of behavior change

As shown in Figure 21, the results of the split Wilcoxon's signed rank tests revealed a statistically significant increase in the app's external motivation on the single runners at the maintenance stage, maintenance stage runners with gamification and female runners at the maintenance stage, but a significant decrease in external motivation on the female runners at the action stage. In detail, the external motivation on the single runners at the maintenance stage (MS + SR) was significantly higher in the second month (Mdn = 4.83) than in the first month (Mdn = 4.25), $z = 2.52$, $p = .049$. The external

motivation on the maintenance stage runners with gamification (MS + YG) was significantly higher in the second month (Mdn = 4.92) than in the first month (Mdn = 4.00), $z = 2.67$, $p = .008$.

Also, the female runners at the maintenance stage (MS + F) showed a statistically significant increase in their rating of the app's external motivation from the first month (Mdn = 2.83) to the second month (Mdn = 4.83), $z = 2.03$, $p = .015$. Meanwhile, the external motivation on the female runners at the action stage (AS + F) significantly decreased from the first month (Mdn = 4.67) to the second month (Mdn = 4.09).

4.2.3. External Motivation by Gamification

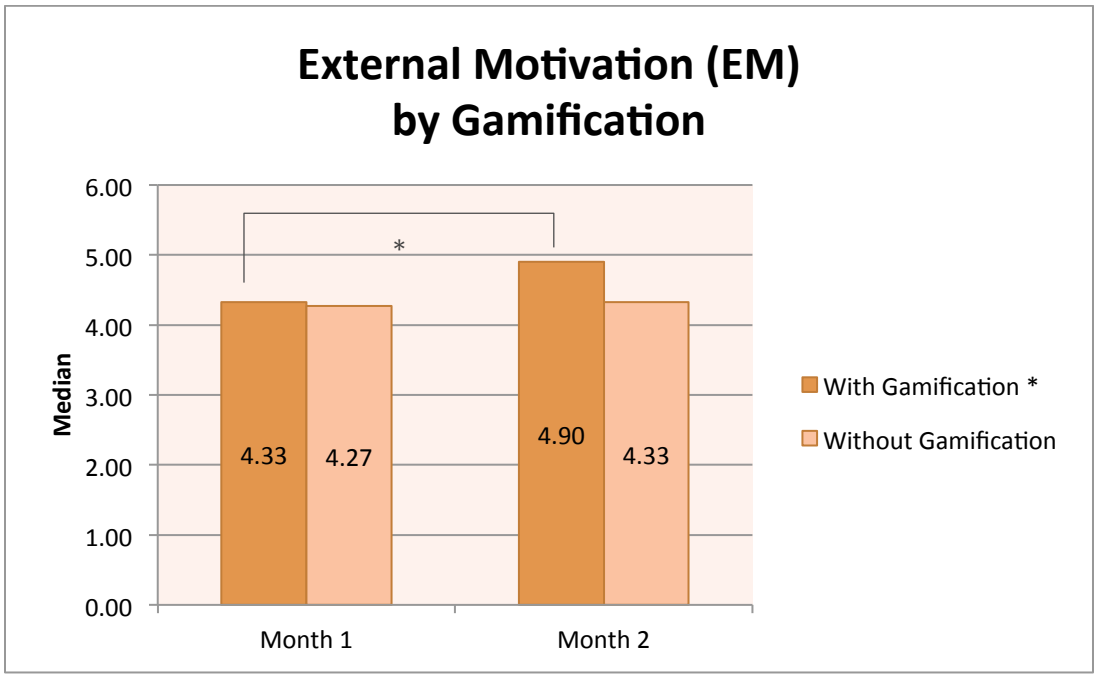

Figure 22. Median value changes of external motivation by gamification

For the runners with gamification, a Wilcoxon signed rank test revealed a statistically significant increase in external motivation from the first month (Mdn = 4.33)

to the second month (Mdn = 4.89), $z = 2.36$, $p = .019$, $r = .43$. However, for the runners without gamification, a Wilcoxon signed rank test did not elicit a statistically significant increase in external motivation from the first month (Mdn = 4.26) to the second month (Mdn = 4.33), $z = 1.03$, $p = .304$, $r = .22$. Thus, hypothesis H3a (presence of gamification will lead to a significant increase in the external motivation of runners) was supported. No significant difference existed between the external motivation change score (second month minus first month) for the runners with gamification and the runners without gamification, t (28) = 1.39, $p = .176$.

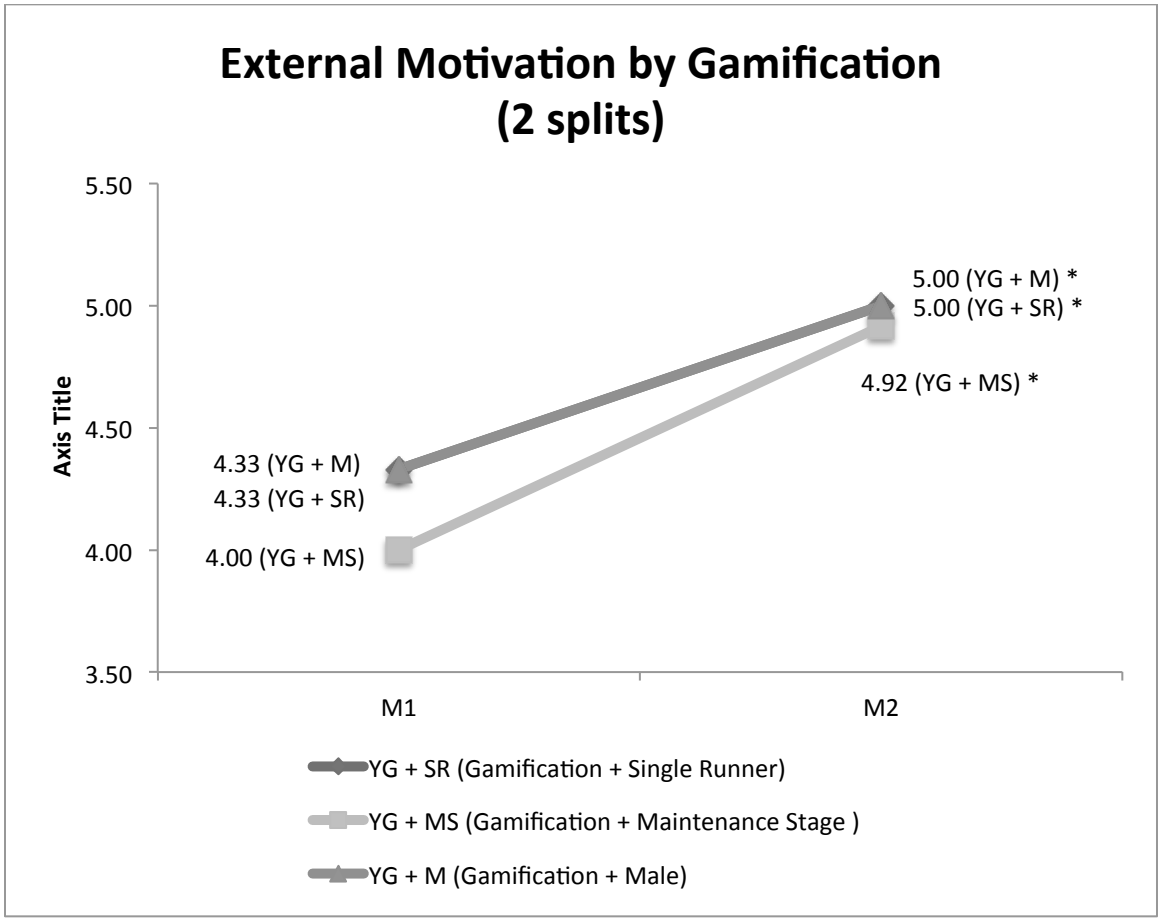

Figure 23. Split result of Wilcoxon signed rank test on external motivation gamifiation

The split Wilcoxon's signed rank tests revealed a statistically significant increase in external motivation on the single runners with gamification, male runners with gamification and maintenance stage runners with gamification. Namely, the external motivation on the single runners with gamification (YG + SR) was significantly increased from the end of the first month (Mdn = 4.33) to the end of the second month (Mdn = 5.00), $z = 2.24$, $p = .025$. Also, the external motivation on the male runners with gamification (YG + M) was significantly higher in the second month (Mdn = 5.00) than in the first month (Mdn = 4.33), $z = 2.43$, $p = .015$. The maintenance stage runners with gamification (YG + MS) also showed a significant increase in their external motivation at the end of the second month (Mdn = 4.92) compared to the end of the first month (Mdn = 4.00), $z = 2.67$, $p = .008$.

4.2.4. External Motivation by Gender

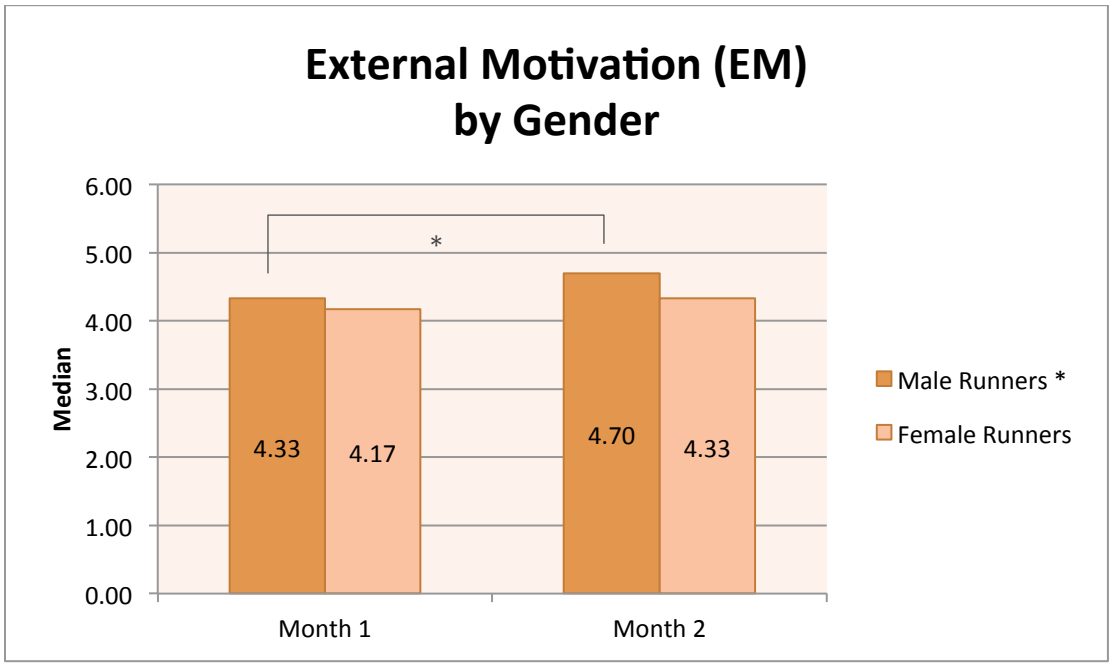

Figure 24. Median value changes of external motivation by gender

A Wilcoxon's signed rank test revealed that the app's external motivation on the male runners was significantly higher at the end of the second month (Mdn = 4.70) than at the end of the first month (Mdn = 4.33), $z = 2.37$, $p = .018$, $r = .43$. However, the external motivation on the female runners was not significantly increased from the first month (Mdn = 4.17) to the second month (Mdn = 4.33), $z = 1.3$, $p = .192$, $r = .24$. Thus, hypothesis H4a (persuasive elements will lead to a significant increase in the external motivation of male runners) was supported, while hypothesis H4e (persuasive elements will lead to a significant increase in the external motivation of female runners) was not supported. No significant differences existed between the male and female runners' external motivation change scores (second month minus first month), $t(28) = -.29$, $p = .775$.

The results of the split Wilcoxon's signed rank tests elicited statistically significant increases for the external motivation on the male runners with gamification, male single runners and female runners at the maintenance stage, but decreases in external motivation on the female runners at the action stage. That is, the app's external motivation on the male single runners (M + SR) was significantly higher in the second month (Mdn = 4.83) than in the first month (Mdn = 4.33), $z = 2.60$, $p = .009$. The male runners with gamification (M + YG) also showed a significant increase in their external motivation at the end of the second month (Mdn = 5.00) from the end of the first month (Mdn = 4 .33), $z = 2.43$, $p = .015$. Although the female runners at the maintenance stage (MS + F) showed a statistically significant increased in their external motivation from the first month (Mdn = 2.83) to the second month (Mdn = 4.83), $z = 2.03$, $p = .015$, the female runners at the action stage (F + AS) showed significantly decreased external

motivation from the first month (Mdn = 4.67) to the second month (Mdn = 4.09), z = 2.37, p = .018.

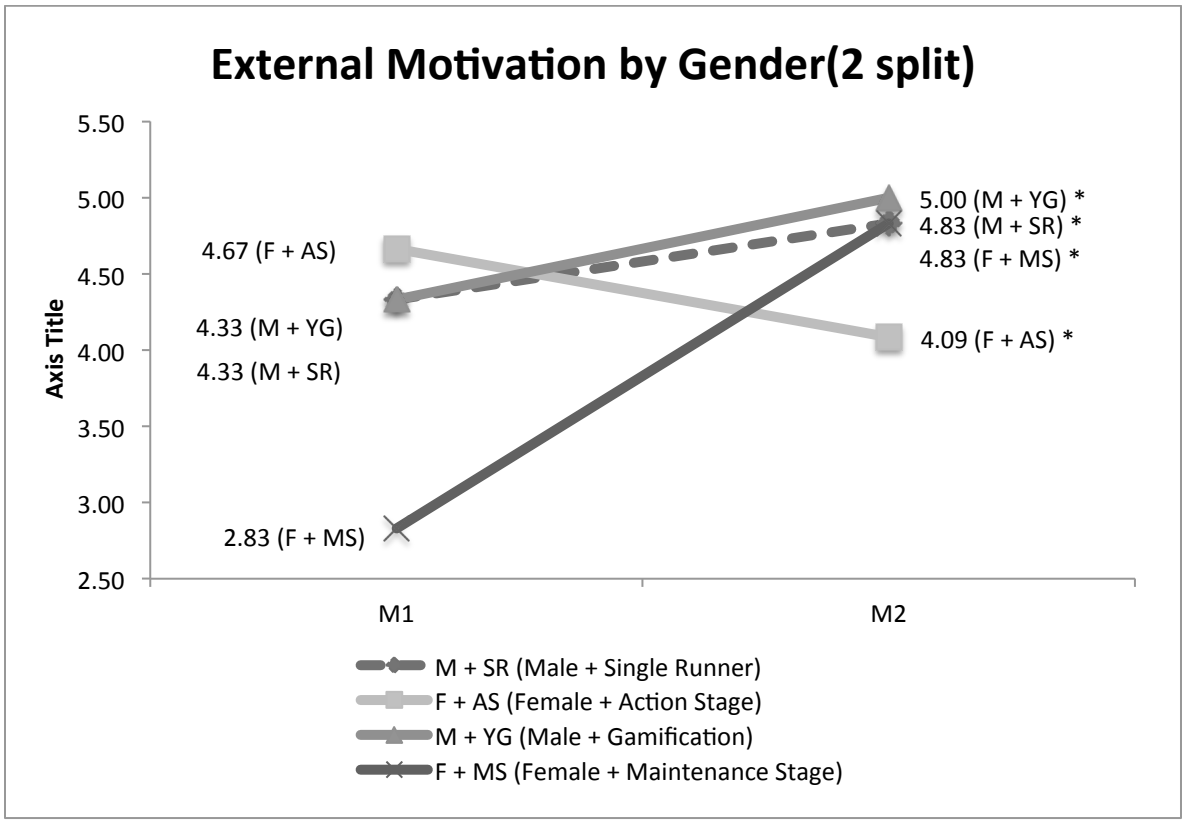

Figure 25. Split result of Wilcoxon signed rank test on external motivation by gender

4.2.5. Summary of External Motivation

The single runner type was found to be the one of the effective factors to show a significant increase in the motivational effect of the HamkeRun application (external motivation). Specifically, runners were motivated externally by the motivational elements provided in the HamkeRun application when they were male in gender, with gamification and at the action stage.

Also, runners at the maintenance stage of the behavior change process were found to have experienced a significant increase in external motivation. Specifically, the single runners at the maintenance stage, maintenance runners with gamification and female runners at the maintenance stage were motivated significantly from the first month to the second month. Reversely, the external motivation on the female runners at the action stage decreased significantly.

Having the gamification elements was one of the factors related to effective external motivation by the application. Significant increases existed from the first month to the second month for the male runners with gamification, single runners with gamification and maintenance runners with gamification. Regarding gender, the male runners showed significant increases in external motivation from the first month to the second month. The details are discussed in the next chapter, including possible reasons why the team runners, female runners and action stage runners were not motivated as much by the application, and other factors that might blur the motivational effects on these groups.

It is important to note that a significant increase in external motivation (the app's motivational effect) is not always good and, simultaneously, an insignificant increase or decrease in external motivation is not always bad. In other words, it would be possible to achieve a target behavior if one person showed sustained levels of external motivation without any significant increase for some amount of time, and then he or she internally operationalized the external motivation as an internal one. To summarize this point, it would be beneficial for runners at the action stage to increase their external motivation

significantly to the appropriate level, which is enough to internalize the motivation if it is maintained.

4.3. Internal Motivation (IM)

Internal motivation was measured to see how much the self-efficacy levels of the participants changed during the study (before the study, at the end of the first month and at the end of the second month). The measured data was collected through seven Likert scale-based questions (0: "Strongly Disagree" to 6: "Strongly Agree").

Table 8. A summary of Friedman's test on internal motivation.

Between-subject factor	**Split by**	**N**	**$\chi 2$**	**Sig.Value**
Runner Type	**Single Runner**	**15**	**10.86**	**.004**
	Team Runner	**15**	**7.05**	**.029**
Stage of Behavior Change	**Action Stage**	**15**	**7.00**	**.030**
	Maintenance Stage	**15**	**12.25**	**.002**
Gamification	**With Gamification**	**18**	**12.20**	**.002**
	Without Gamification	12	5.10	.052
Gender	**Male**	**19**	**9.56**	**.008**
	Female	**11**	**9.80**	**.007**

Non-parametric Friedman tests were employed due to the small sample size, the data type (ordinal scale) and property (within-subject factors across three time points). Table 8 shows a summary of the test results on internal motivation. The results were categorized using four between-subject factors: runner type, stage of behavior change, gamification and gender.

4.3.1. Internal Motivation by Runner Type

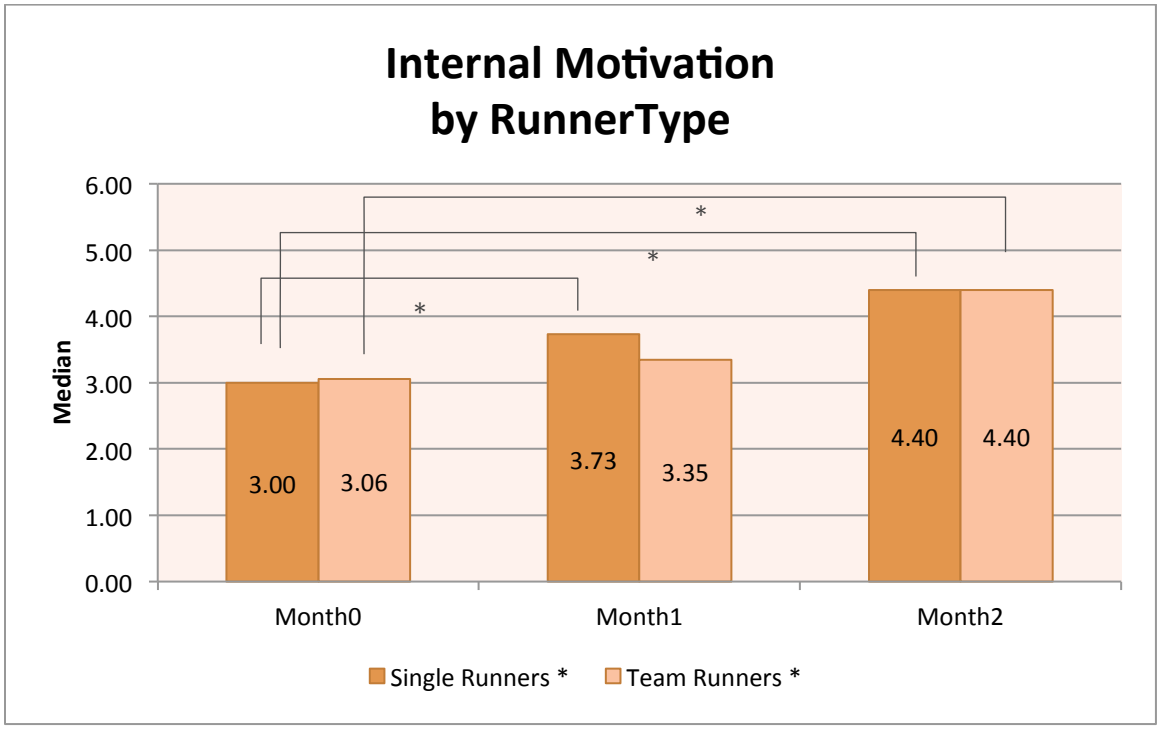

Figure 26. Median value changes of internal motivation by runner type

The results of the Friedman tests indicated statistically significant differences existed in the internal motivation of the single runners $\chi^2(2, n = 15) = 10.86, p = .004$ and team runners $\chi^2(2, n = 15) = 7.05, p = .029$ across the three time points (before the study, at the end of the first month and at the end of the second month). These results supported hypotheses H1b (social elements will lead to a significant increase in the internal motivation of single runners) and H1f (social elements will lead to a significant increase in the internal motivation of team runners). Inspection of the median values for the single runners showed increases in internal motivation from the beginning of the study (Mdn = 3.00), to the end of the first month (Mdn = 3.73) and to the end of the second month (Mdn = 4.40). For the team runners, the median values also increased from

the beginning (Mdn = 3.06), to the end of the first month (Mdn = 3.35) and to the end of the second month (Mdn = 4.40). Wilcoxon tests with a Bonferroni correction were used to follow up on this finding. The results showed that the internal motivation of single runners was changed significantly from the beginning of the study to the end of the first month, $z = -2.56$, $p < .05$ and $r = -0.47$, and from the beginning of the study to the end of the second month, $z = -2.92$, $p < .05$, and $r = -0.53$. The internal motivation of the team runners was also significantly changed from the beginning of the study to the end of the second month, $z = -2.47$, $p < .05$ and $r = -0.07$. However, the changes in internal motivation from the first month to the second month for both the single runners and team runners were not significant. No significant differences existed between the single runners' and team runners' internal motivation change scores (second month minus beginning of the study), $t\ (28) = .19$, $p = .848$.

4.3.2. Internal Motivation by Stage of Behavior Change

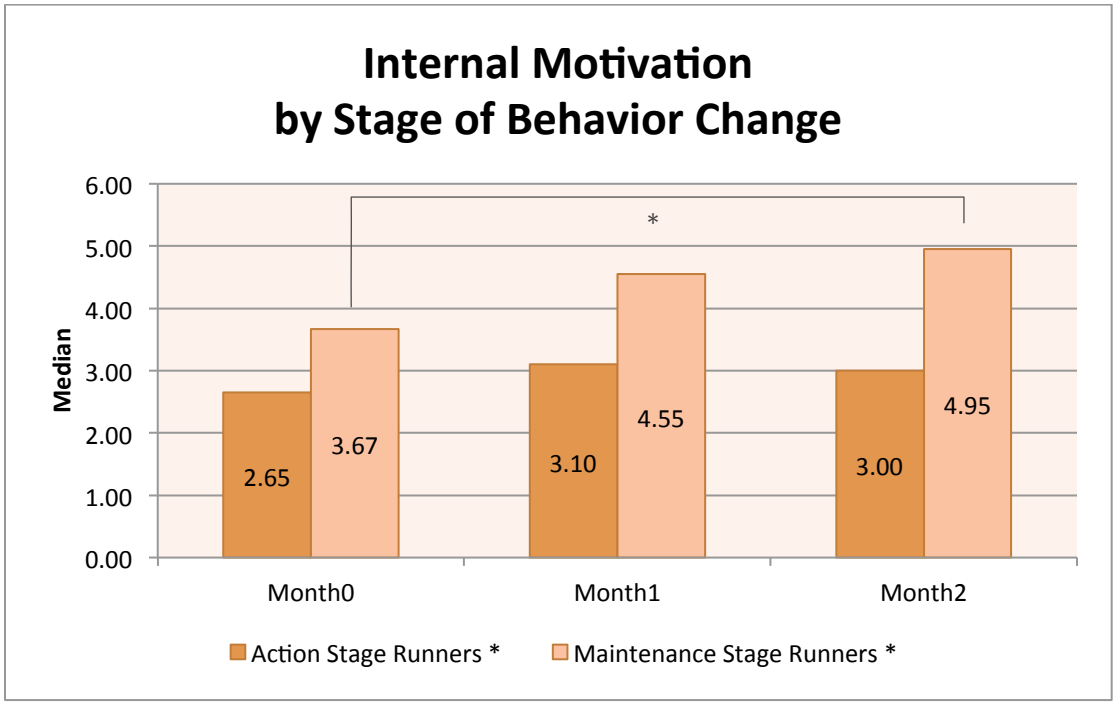

Figure 27. Median value changes of internal motivation by stage of behavior change

The Friedman test results also indicated statistically significant differences existed in the internal motivation scores of the runners at the action stage, $\chi^2(2, n = 30) = 7.00$, $p = .03$, and runners at the maintenance stage, $\chi^2(2, n = 30) = 12.25$, $p = .002$) across the three time points. These results supported hypotheses H2b (persuasive elements will lead to a significant increase in the internal motivation of runners at the maintenance stage) and H2f (persuasive elements will lead to a significant increase in the internal motivation of runners at the action stage). Inspection of the median values showed that the internal motivation scores of the runners at the maintenance stage increased steadily (Mdn = 3.67 at the beginning of the study, Mdn = 4.55 at the end of the first month, and Mdn = 4.95 at the end of the second month), but those scores of the runners at the action stage did not (Mdn = 2.65 at the beginning of the study, Mdn = 3.10 at the end of the first month, and

Mdn = 3.00 at the end of the second month). A post hoc analysis using the Wilcoxon signed-rank test with a Bonferroni correction was also conducted to see the significant differences. The results revealed that the internal motivation of the runners at the maintenance stage significantly changed from the beginning of the study to the end of the second month, z = -1.28, $p < 0.005$, and r = -0.23. A significant difference existed between the runners at the action stage and the runners at the maintenance stage in regard to their internal motivation change score (second month minus beginning of the study), t (28) = -2.23, p = .034.

4.3.3. Internal Motivation by Gamification

In terms of gamification, the Friedman test revealed that statistically significant differences existed in the internal motivation of the runners with gamification, χ^2(2, n = 30) = 12.2, p = .002). This result supported hypothesis H3b (presence of gamification will lead to a significant increase in internal motivation). The median values of the internal motivation of the runners with gamification steadily increased from the beginning of the study (Mdn = 3.48), to the end of the first month (Mdn = 3.70) and to the end of the second month (Mdn = 4.63). However, no statistically significant difference was found in the internal motivation of the runners without gamification, χ^2(2, n = 30) = 5.10, p = .052.

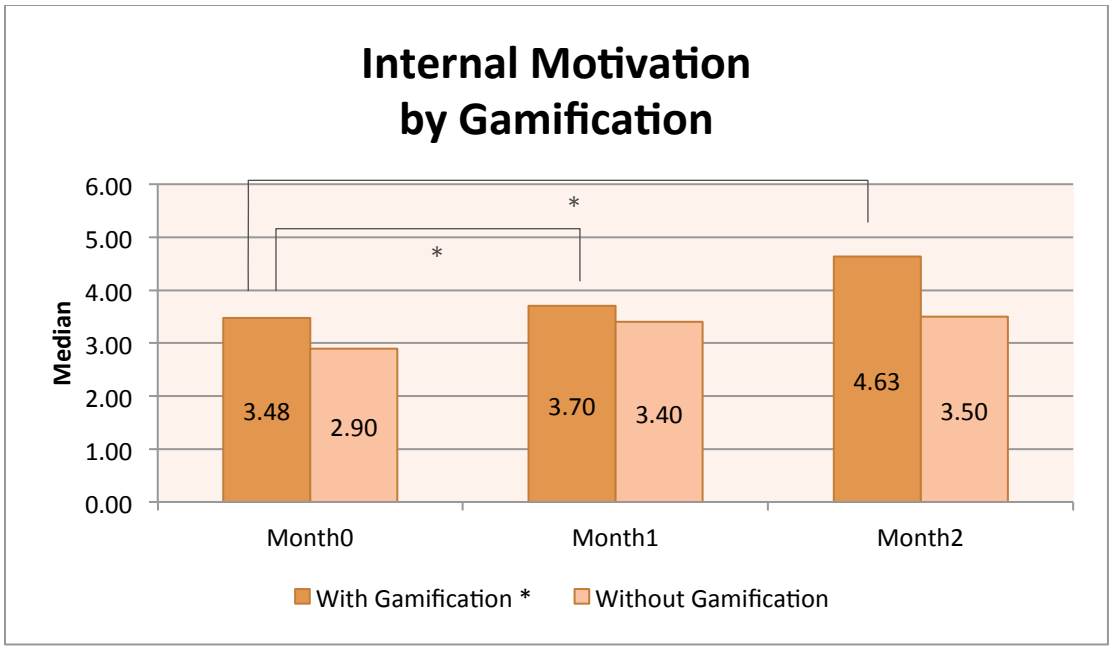

Figure 28. Median value changes of internal motivation by gamification.

A post-hoc test using a Wilcoxon signed rank test with a Bonferroni correction showed that the internal motivation of the runners with gamification significantly changed from the beginning of the study to the end of the first month, $z = -2.42$, $p < .05$ and $r = -0.44$, and from the beginning of the study to the end of the second month, $z = -3.33$, $p < .05$, and $r = -0.61$. However, the changes in the internal motivation from the first month to the second month for the runners with gamification were not significant. Also, the distributions of the internal motivation of the runners without gamification at the beginning of the study, at the end of the first month and at the end of the second month were not significantly different. No significant differences existed in the internal motivation change scores (second month minus beginning of the study) between the runners with gamification and the runners without gamification, $t\ (28) = .05$, $p = .962$.

4.3.4. Internal Motivation by Gender

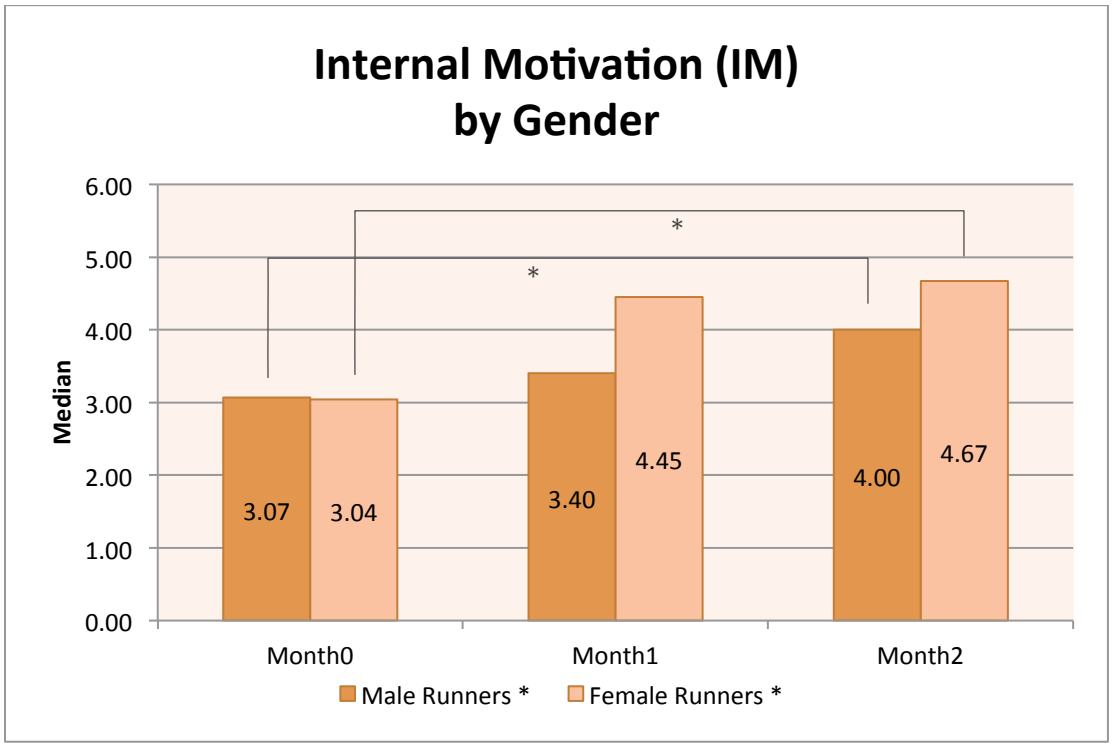

Figure 29. Median value changes of internal motivation by gender.

For internal motivation by gender, the Friedman test indicated that statistically significant differences existed across the three time points, $\chi^2(2, n = 30) = 9.56$, $p = .008$) for the male runners and $\chi^2(2, n = 30) = 9.80$, $p = .007$) for the female runners. These results supported hypotheses H4b (persuasive elements will lead to a significant increase in the internal motivation of male runners) and H4f (persuasive elements will lead to a significant increase in the internal motivation of female runners). The median values of the internal motivation of the male runners increased from the beginning of the study (Mdn = 3.07), to the end of the first month (Mdn = 3.40) to the end of the second month (Mdn = 4.00). For the female runners, the median values for internal motivation also increased (Mdn = 3.04 at the beginning; Mdn = 4.45 at the end of the first month; Mdn =

4.67 at the end of the second month). The Wilcoxon tests with a Bonferroni correction showed that the internal motivation of the male runners changed significantly from the beginning of the study to the end of the second month, z = -3.00, p < .05 and r = -0.55, and that the internal motivation of the female runners also significantly changed from at the beginning of the study to the end of the first month, z = -2.77, p < .05 and r = -0.51. No significant differences existed between the male and female runners' internal motivation change scores (second month minus beginning of the study), t (28) = -.54, p = .592.

4.3.5. Results of Split Friedman's Tests on Internal Motivation

Additional split Friedman's tests on internal motivation were conducted in combinations of four between-subject factors (i.e., runner type, stage of behavior change, gamification and gender) in order to explore the potential differences in the subgroups that might have been obscured in the larger group analyses.

Table 9. A summary of 2 split Friedman's test on internal motivation

	Split by		***N***	***χ2***	**Sig.**
Runner type x Stage of behavior change	**Single Runner**	**Action Stage**	7	**6.32**	**.042**
	Single Runner	Maintenance Stage	8	4.84	.089
	Team Runner	Action Stage	8	2.77	.250
	Team Runner	**Maintenance Stage**	7	**9.54**	**.008**
Runner type x Gamification	**Single Runner**	**Gamification**	9	**6.34**	**.042**
	Single Runner	**No Gamification**	6	**6.38**	**.041**

	Team Runner	**Gamification**	9	**6.23**	**.044**
	Team Runner	No Gamification	6	1.46	.483
Runner type x Gender	**Single Runner**	**Male**	11	**9.48**	**.009**
	Single Runner	Female	4	4.43	.109
	Team Runner	Male	8	1.36	.508
	Team Runner	**Female**	7	**7.15**	**.028**
Stage of behavior change x Gamification	**Action Stage**	**Gamification**	8	**6.07**	**.048**
	Action Stage	No Gamification	7	1.62	.446
	Maintenance Stage	**Gamification**	10	**7.20**	**.027**
	Maintenance Stage	No Gamification	5	5.77	.056
Stage of behavior change x Gender	**Action Stage**	**Male**	11	**6.05**	**.049**
	Action Stage	Female	4	5.10	.078
	Maintenance Stage	Male	8	1.86	.395
	Maintenance Stage	**Female**	7	**9.77**	**.008**
Gamification x Gender	**Gamification**	**Male**	11	**6.19**	**.045**
	Gamification	Female	8	4.07	.131
	No Gamification	Male	7	8.07	.018
	No Gamification	Female	4	2.00	.368

4.3.5.1. Runner Type + Stage of Behavior Change

The split Friedman tests (split by runner type and stage of the behavior change process) revealed that statistically significant differences existed in the internal motivation scores across time for the single runners at the action stage, $\chi^2(2, n = 7) = 6.32$, $p = .042$, and team runners at the maintenance stage, $\chi^2(2, n = 8) = 9.54$, $p = .008$

(Figure 29). However, no significant differences existed for the single runners at the maintenance stage or for the team runners at the action stage. The Wilcoxon tests with a Bonferroni correction revealed that the internal motivation of the team runners at the maintenance stage changed significantly from the beginning of the study to the end of the second month, $z = -2.94$, $p < .05$ and $r = -0.54$.

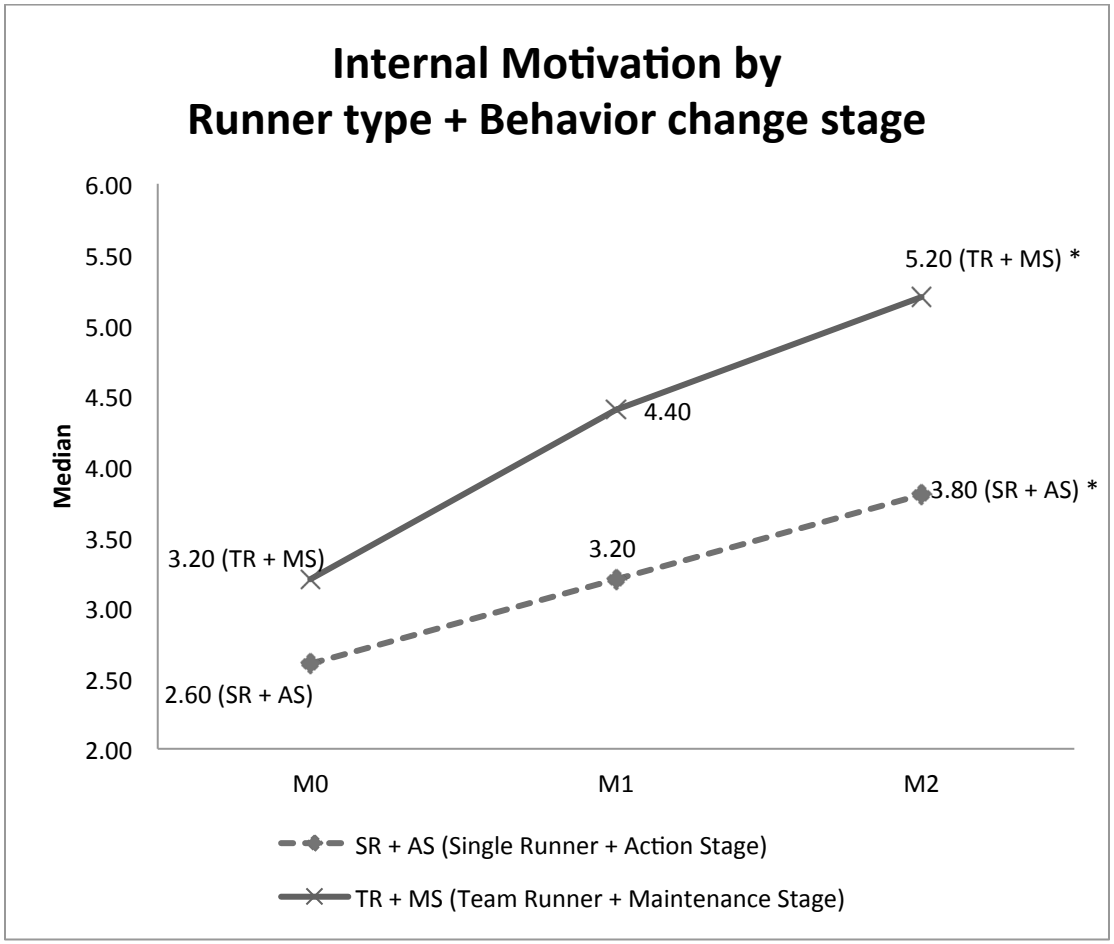

Figure 30. Split result of Freidman's test on internal motivation by runner type + stage of behavior change

4.3.5.2. Runner Type + Gamification

As shown in Table 9, the split Friedman tests (split by runner type and gamification) revealed that statistically significant differences existed in the internal motivation scores across time for the single runners with gamification, $\chi^2(2, n = 9) = 6.34$, $p = .042$, single runners without gamification, $\chi^2(2, n = 6) = 6.38$, $p = .041$, and team runners with gamification, $\chi^2(2, n = 9) = 6.23$, $p = .044$. However, no significant differences were found for the team runners without gamification. A post hoc analysis with the Wilcoxon signed-rank test with a Bonferroni correction was also conducted in order to see the significant differences. The results revealed that the internal motivation of the single runners with gamification significantly changed from the beginning of the study to the end of the second month, $z = -2.48$, $p < 0.05$, and $r = -0.45$.

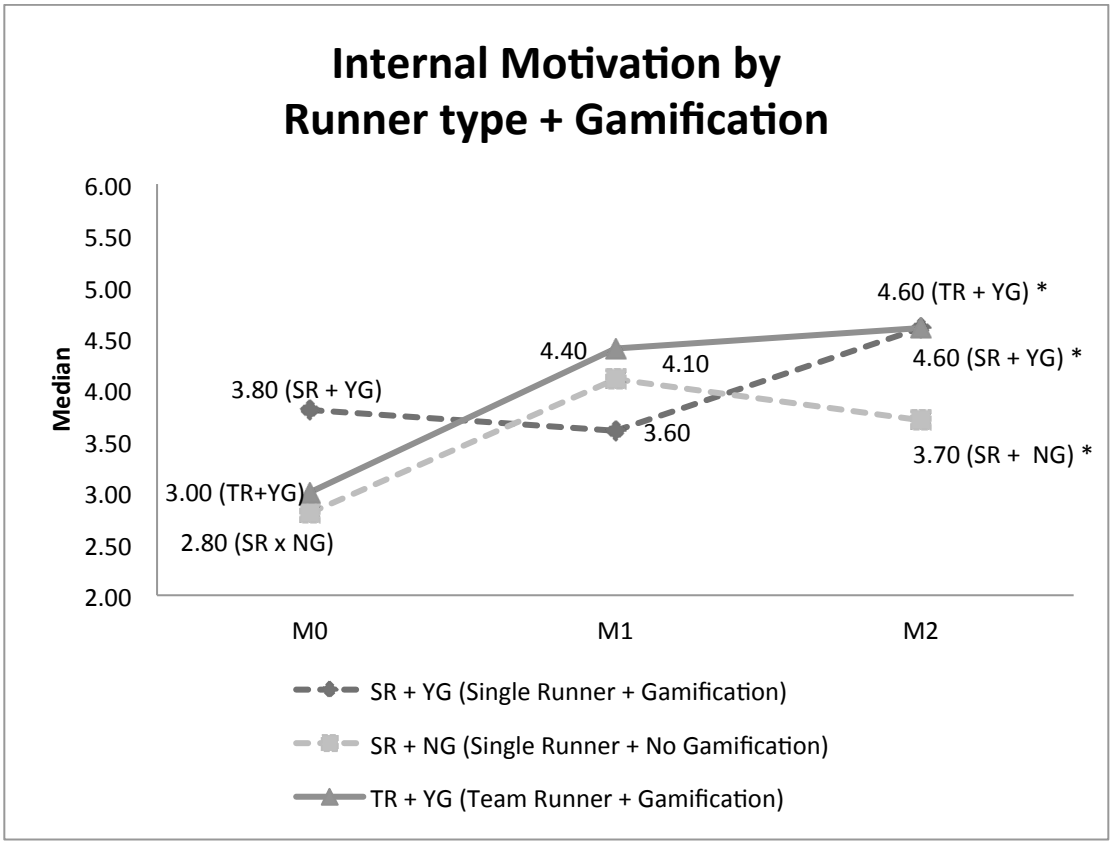

Figure 31. Split result of Freidman's test on internal motivation by runner type + gamification.

4.3.5.3. Runner Type + Gender

The results of the split Friedman tests (split by runner type and gender) revealed that statistically significant differences existed in the internal motivation scores across time for the male single runners, $\chi^2(2, n = 11) = 9.48$, $p = .009$, and female team runners, $\chi^2(2, n = 8) = 7.15$, $p = .028$. However, no significant differences exited for the internal motivation of the female single runners and male team runners. A post hoc analysis with the Wilcoxon signed-rank tests with a Bonferroni correction was also employed to see the significant differences between two time points. The results revealed that the internal motivation of the male single runners significantly changed from the beginning of the study to the end of the second month, $z = -2.99$, $p < 0.05$ and $r = -0.55$, and that the internal motivation of the female team runners significantly changed from the beginning of the study to the end of the second month, $z = -2.41$, $p < 0.05$, and $r = -0.44$.

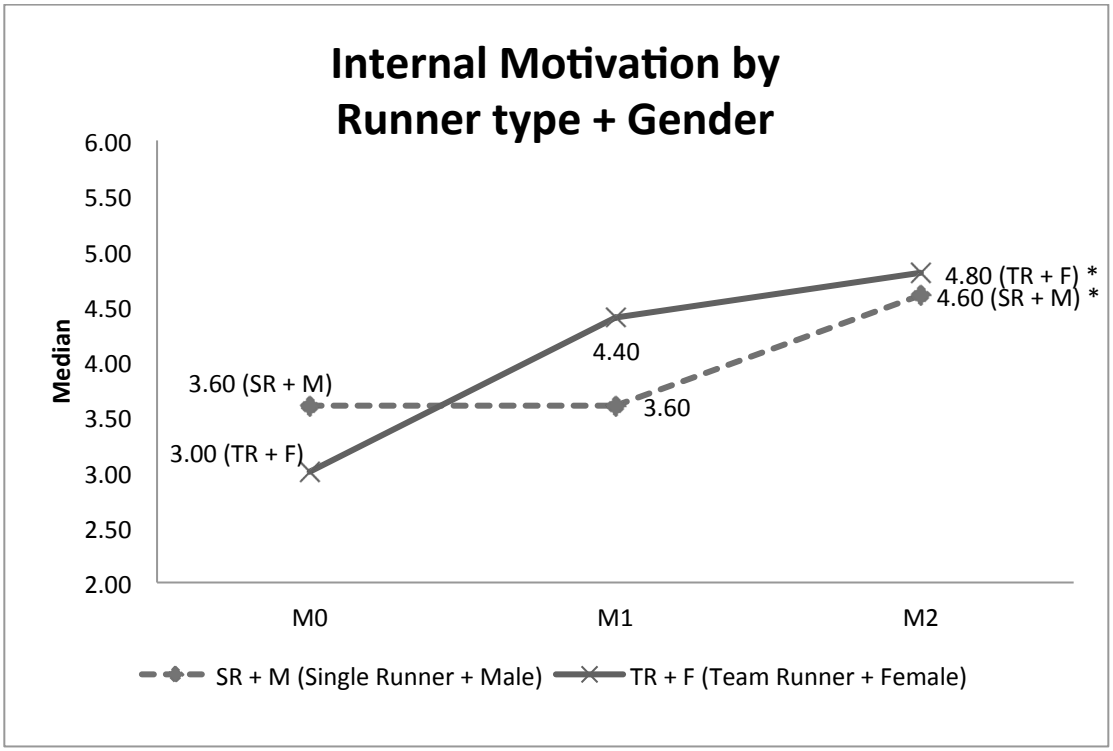

Figure 32. Split result of Freidman's test on internal motivation by runner type + gender.

4.3.5.4. Stage of Behavior Change + Gamification

In a split by stage of behavior change and gamification, the Friedman tests revealed that statistically significant differences existed in the internal motivation scores across time for the action stage runners with gamification, $\chi^2(2, n = 8) = 6.07$, $p = .048$, and maintenance stage runners with gamification, $\chi^2(2, n = 10) = 7.20$, $p = .027$. A post hoc analysis with the Wilcoxon signed-rank test with a Bonferroni correction revealed that the internal motivation of the maintenance stage runners with gamification significantly changed from the beginning of the study to the end of the second month, $z = -2.69$, $p < 0.005$, and $r = -0.49$. However, no significant differences were found for the runners without gamification both at the action and maintenance stages.

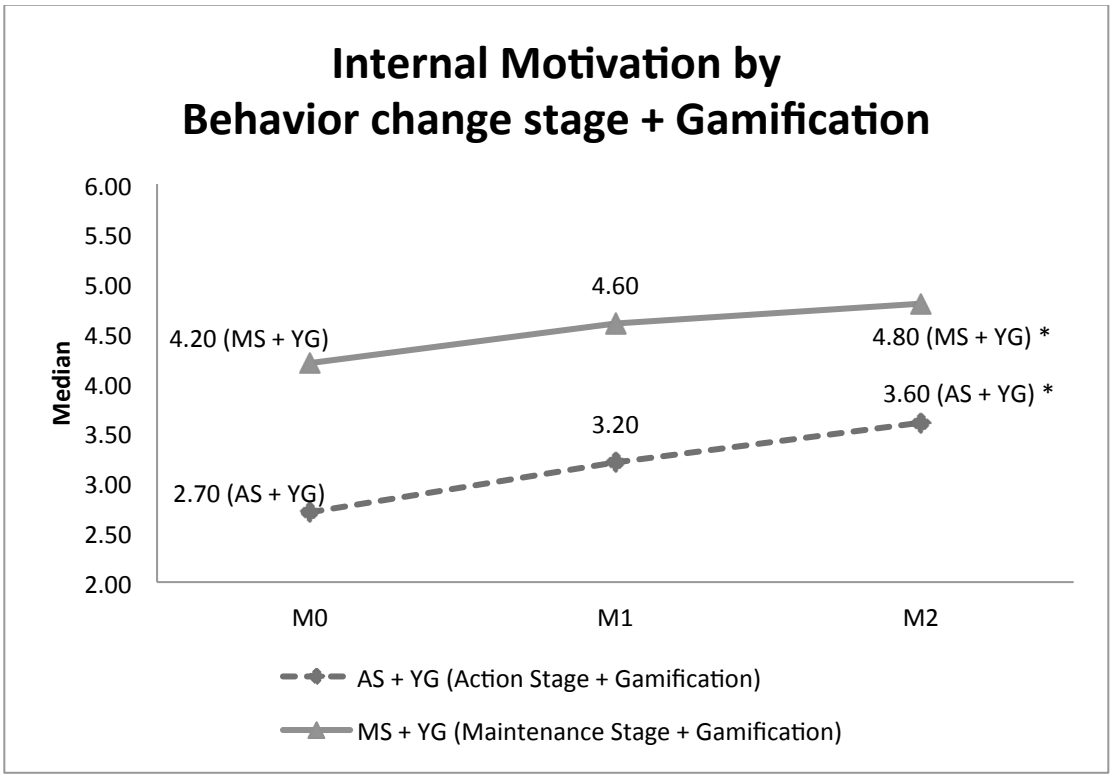

Figure 33. Split result of Freidman's test on internal motivation by stage of behavior change + gamification

4.3.5.5. Stage of Behavior Change + Gender

Two split Friedman tests (split by stage of behavior change and gender) elicited statistically significant differences in the internal motivation scores across time for the male runners at the action stage, $\chi^2(2, n = 11) = 6.05$, $p = .049$, and female runners at the maintenance stage, $\chi^2(2, n = 7) = 9.77$, $p = .008$. The Wilcoxon tests with a Bonferroni correction showed that the internal motivation of the female runners at the maintenance stage changed significantly from the beginning of the study to the end of the first month, $z = -2.54$, $p < .05$ and $r = -0.46$, and from the beginning of the study to the end of the second month, $z = -2.67$, $p < .05$ and $r = -0.49$.

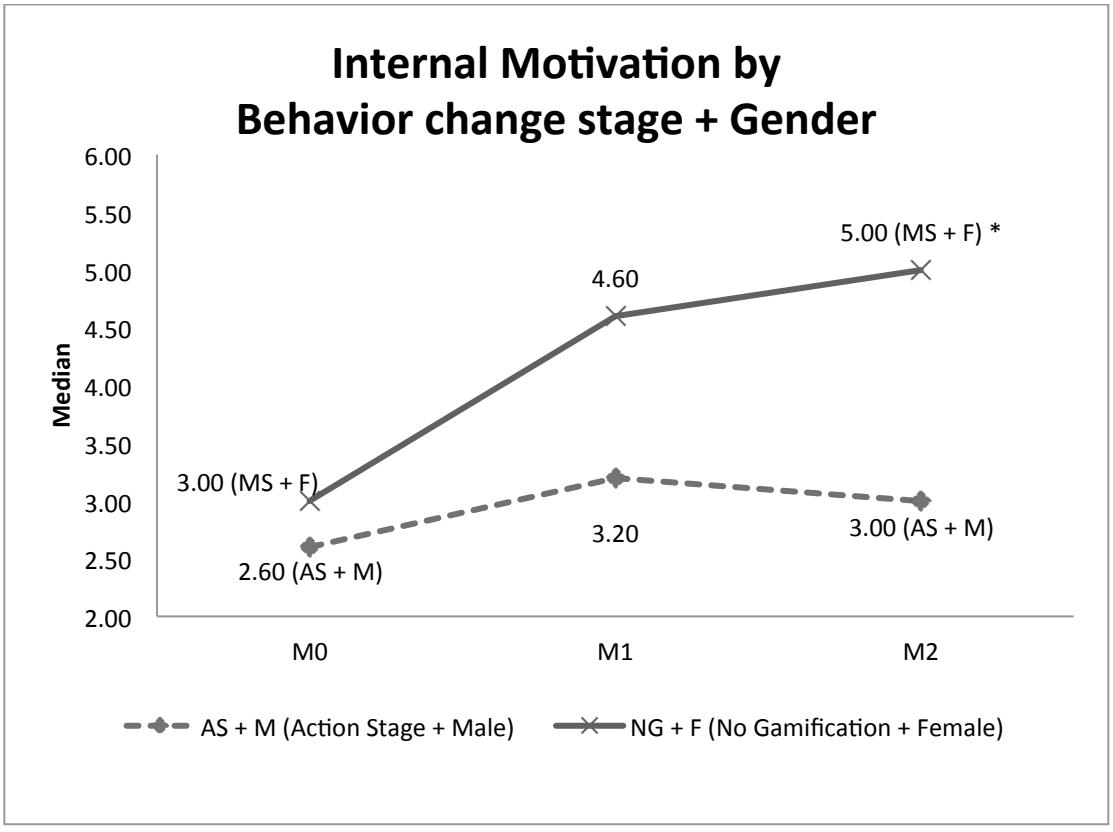

Figure 34. Split result of Freidman's test on internal motivation by stage of behavior change + gender

4.3.5.6. Gamification + Gender

The split Friedman tests (split by gamification and gender) showed that statistically significant differences existed in the internal motivation scores across time for the male runners with gamification, $\chi^2(2, n = 11) = 6.19$, $p = .045$, and male runners without gamification, $\chi^2(2, n = 8) = 8.07$, $p = .018$. However, no significant differences were found for the female runners regardless of gamification. The Wilcoxon tests with a Bonferroni correction showed that the internal motivation of the male runners with gamification changed significantly from the beginning of the study to the end of the second month, $z = -2.45$, $p < .05$ and $r = -0.45$, and the internal motivation of the male runners without gamification also significantly changed from the beginning of the study to the end of the second month, $z = -2.54$, $p < .05$, and $r = -0.46$. However, the changes in the internal motivation of the female runners regardless of gamification were not significant.

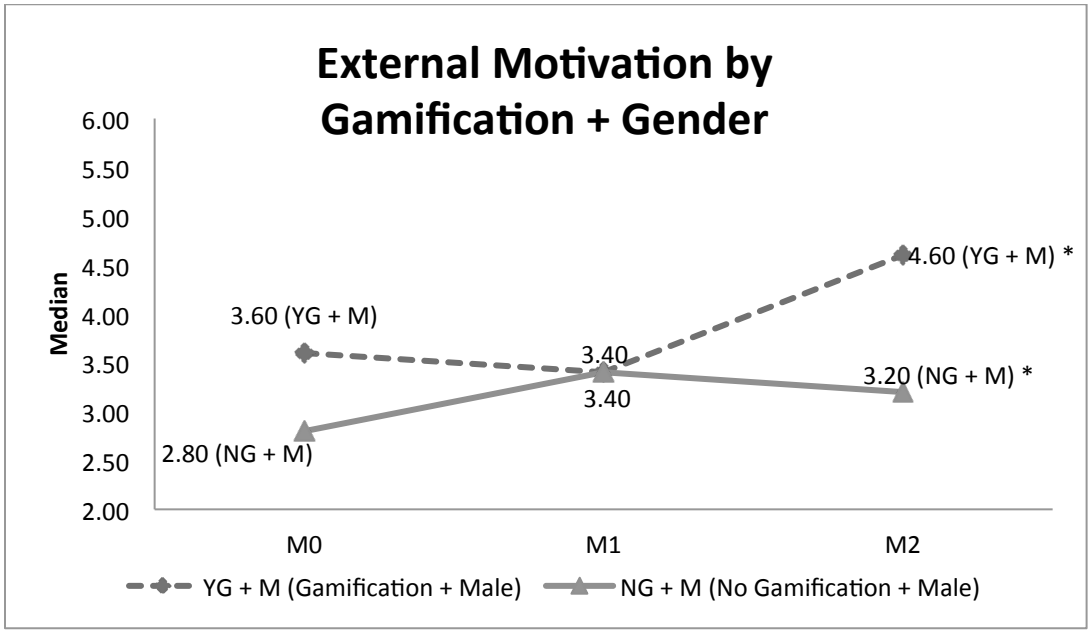

Figure 35. Split result of Freidman's test on internal motivation by gamification + gender

4.3.6. Summary of Internal Motivation

To summarize, internal motivation was increased significantly by runner type, stage of the behavior change process, gamification and gender (male). Both the single and team runner types were found to show significant increases in internal motivation across the three time points (at the beginning of the study, at the end of the first month and at the end of the second month). Specifically, the single runner types showed significantly increased internal motivation when they were male in gender, at the action stage and with or without gamification. The team runner types showed significantly increased internal motivation when they were with gamification and at the maintenance stage.

With respect to the behavior change stage, maintenance runners showed significant increases in their internal motivation when they were team runners, with gamification and female in gender. In addition, the action stage runners showed significant increases in their internal motivation when they were single runners, with gamification and male in gender.

Having gamification significantly increased internal motivation. While the runners without gamification did not show any significant change in internal motivation, the runners with gamification showed significant increases regardless of their runner type and behavior change stage. In terms of gender, only the male runners, regardless of the presence of gamification, showed a significant increase in internal motivation. The female runners did not seem to be influenced by gamification. More details are discussed in section 5.3.

4.4. Satisfaction (SF)

Satisfaction was measured in order to investigate how much the runners were satisfied with the concepts of the information visualization, gamification and social competition (or cooperation), on the whole, as provided in the HamkeRun application. The measured data was collected through seven Likert scale-based questions (0: "Strongly Disagree" to 6: "Strongly Agree"). Due to the collected data type (ordinal scale) and small sample size, non-parametric Wilcoxon's signed rank tests were employed.

Table 10. A summary of Wilcoxon signed test on satisfaction

Between subject factor	**Split by**	*N*	***Z***	**Sig. Value**
Runner Type	**Single Runner**	15	**1.99**	**.047**
Runner Type	Team Runner	15	-0.24	.812
Stage of Behavior Change	Action Stage	15	-0.18	.858
Stage of Behavior Change	**Maintenance Stage**	15	**2.17**	**.030**
Gamification	With Gamification	18	0.92	.359
Gamification	Without Gamification	12	0.91	.365
Gender	Male	19	0.44	.662
Gender	Female	11	1.44	.151

4.4.1. Satisfaction by runner type

A Wilcoxon's signed rank test revealed that the satisfaction of the single runners was significantly higher at the end of the second month (Mdn = 4.06) than the end of the first month (Mdn = 3.59), $z = 1.99$, $p = .047$, $r = .36$. This information supported H1c (social elements will lead to a significant increase in the satisfaction of single runners).

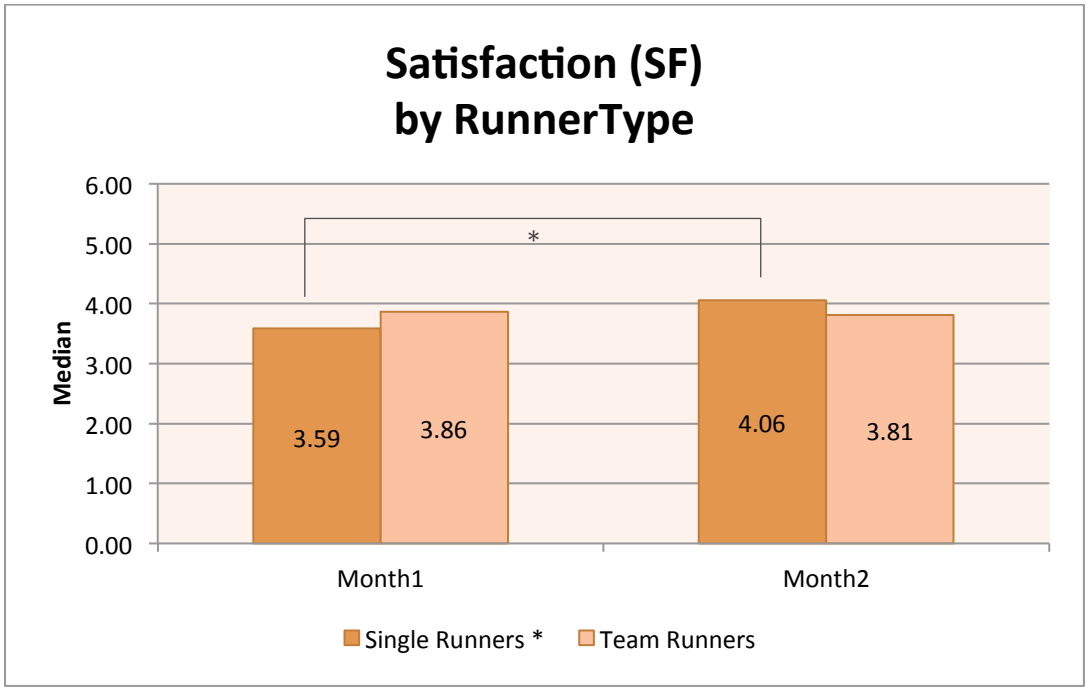

Figure 36. Median value changes of satisfaction by runner type.

However, for the team runners, a Wilcoxon signed rank test did not elicit a statistically significant change in satisfaction from the first month (Mdn = 3.86) to the second month (Mdn = 3.81), z = -.24, p = .812, r = -.04. Therefore, H1g (Social elements will lead to significant increase in satisfaction of team runners) was not supported. No significant difference existed between the single and team runners' satisfaction change scores (second month minus first month), t (28) = 1.76, p = .089.

In order to explore the potential differences in the subgroups that might have been obscured in the larger group analyses, additional split Wilcoxon tests on satisfaction were conducted in combinations among four between-subject factors: runner type, stage of behavior change, gamification and gender (Table 11).

Table 11. A summary of split Wilcoxon signed test on satisfaction

	Split by		*N*	*z*	**Sig.**
Runner type x Stage of behavior change	Single Runner	Action Stage	7	0.37	.713
	Single Runner	**Maintenance Stage**	**8**	**2.41**	**.016**
	Team Runner	Action Stage	8	-0.51	.611
	Team Runner	Maintenance Stage	7	0.41	.680
Runner type x Gamification	Single Runner	Gamification	9	0.95	.343
	Single Runner	**No Gamification**	**6**	**2.07**	**.038**
	Team Runner	Gamification	9	0.28	.778
	Team Runner	No Gamification	6	-0.74	.461
Runner type x Gender	Single Runner	Male	11	1.19	.223
	Single Runner	Female	4	1.86	.063
	Team Runner	Male	8	-0.96	.336
	Team Runner	Female	7	0.51	.611
Stage of behavior change x Gamification	Action Stage	Gamification	8	-0.53	.599
	Action Stage	No Gamification	7	0.69	.492
	Maintenance Stage	**Gamification**	**10**	**2.16**	**.031**
	Maintenance Stage	No Gamification	5	0.74	.461
Stage of behavior change x Gender	Action Stage	Male	11	-0.34	.734
	Action Stage	Female	4	1.41	.157
	Maintenance Stage	Male	8	0.37	.715
	Maintenance Stage	Female	7	1.72	.086
Gamification x Gender	Gamification	Male	11	0.17	.865
	Gamification	Female	8	1.19	.233
	No Gamification	Male	7	0.69	.492
	No Gamification	Female	4	0.74	.461

The split Wilcoxon's signed rank tests (split by runner type and stage of the behavior change process and split by runner type and gamification) showed that the satisfaction of the single runners at the maintenance stage (SR + MS) was significantly higher in the second month (Mdn = 4.25) than in the first month (Mdn = 3.82), $z = 2.41$, $p = .016$, and the satisfaction of single runners without gamification (SR + NG) also significantly increased from the first month (Mdn = 3.25) to the second month (Mdn = 3.75), $z = 2.07$, $p = .038$. However, for the single runners at the action stage, single runners with gamification and team runners (regardless of gamification or stage of the behavior change process), their satisfaction did not significantly change from the first month to the second month.

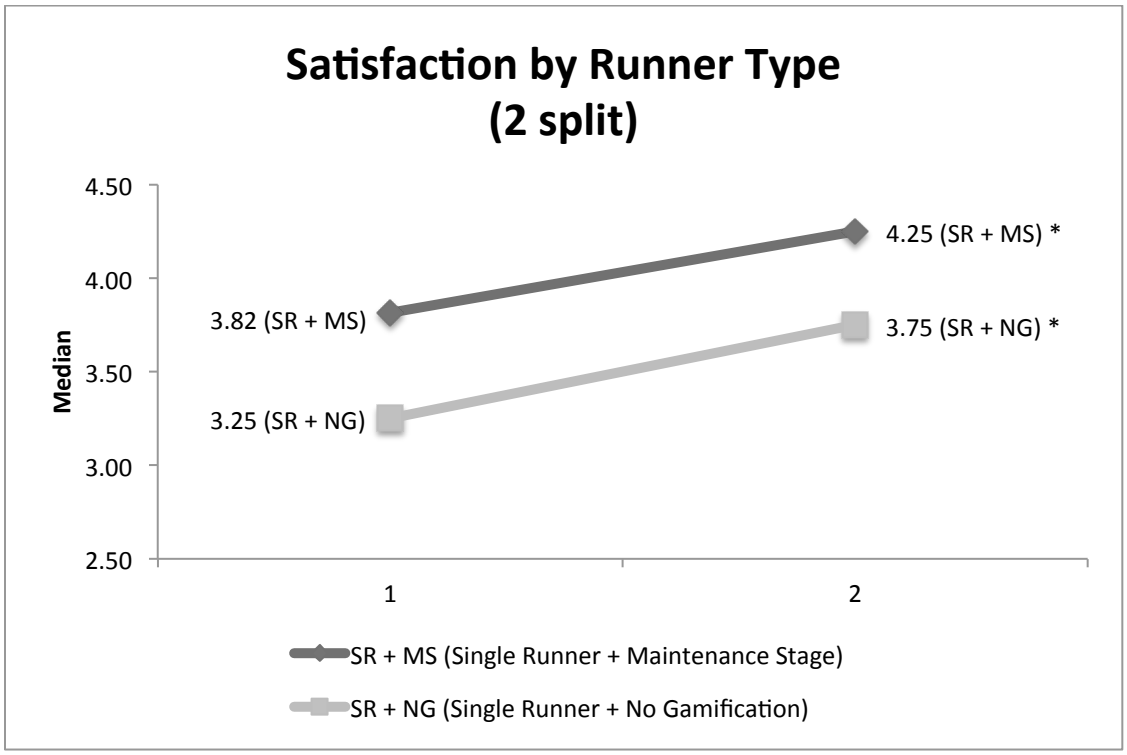

Figure 37. Split result of Wilcoxon signed test on satisfaction by runner type

4.4.2. Satisfaction by Stage of Behavior Change

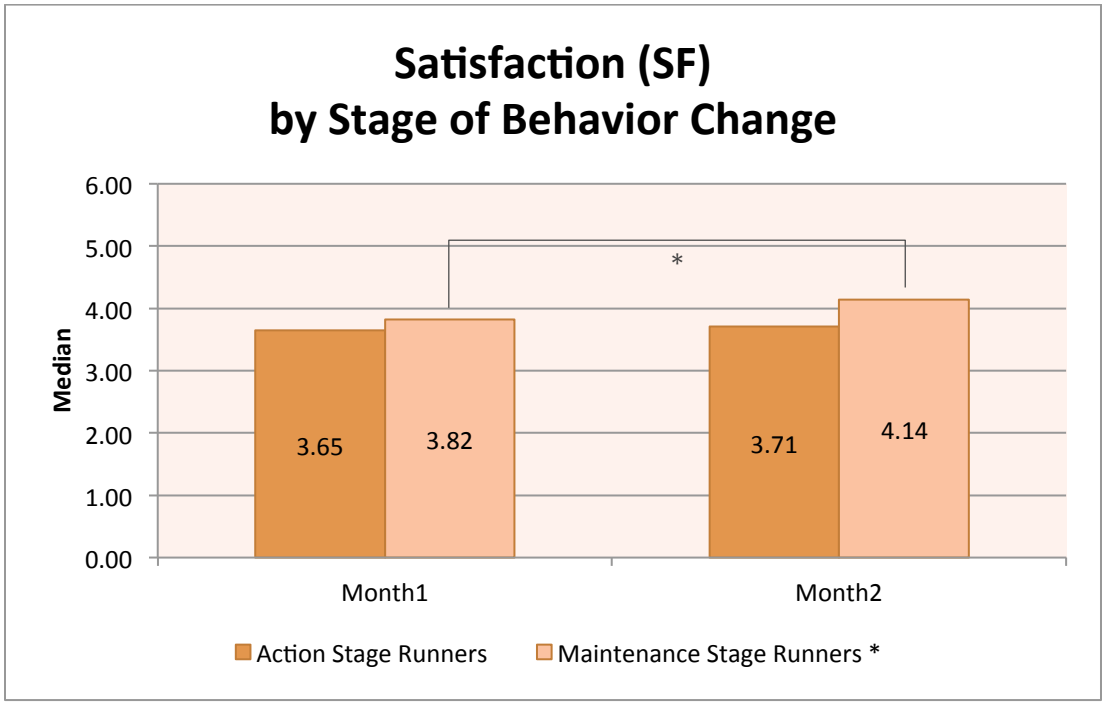

Figure 38. Median value changes of satisfaction by stage of behavior change.

A Wilcoxon signed rank test revealed that the satisfaction of the runners at the maintenance stage significantly increased from the first month (Mdn = 3.82) to the second month (Mdn = 4.14), $z = 2.17$, $p = .03$, $r = .04$. However, for runners at the action stage, their satisfaction did not significantly change from the first month (Mdn = 3.65) to the second month (Mdn = 3.71). Thus, H2c (persuasive elements will lead to a significant increase in the satisfaction of runners at the maintenance stage) was supported, while H2g (persuasive elements will lead to a significant increase in the satisfaction of runners at the maintenance stage) was not supported. No significant differences existed between the action stage runners' and maintenance stage runners' satisfaction change scores (second month minus first month), t (28) = -1.58, $p = .126$.

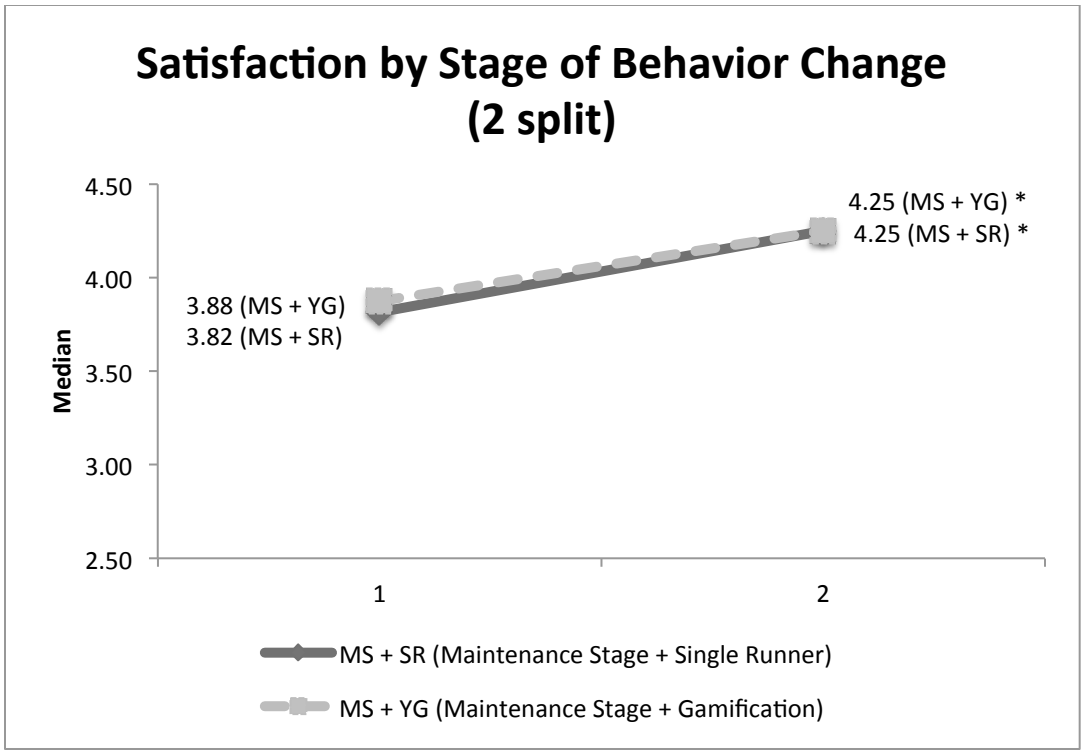

Figure 39. Split result of Wilcoxon signed test on satisfaction by stage of behavior change.

The split Wilcoxon's signed rank tests (split by stage of behavior change and runner type and split by stage of behavior change and gamification) revealed that the satisfaction of the maintenance runners with gamification (MS + YG) was significantly higher in the second month (Mdn = 4.25) than in the first month (Mdn = 3.87), $z = 2.16$, $p = .031$. Also, the satisfaction of the single runners at the maintenance stage (SR + MS) was significantly higher in the second month (Mdn = 4.25) than in the first month (Mdn = 3.82), $z = 2.41$, $p = .016$. However, for the maintenance stage runners without gamification and action stage runners regardless of gamification, their results did not show a significant increase or decrease in their satisfaction from the first month to the second month.

4.4.3. Satisfaction by Gamification

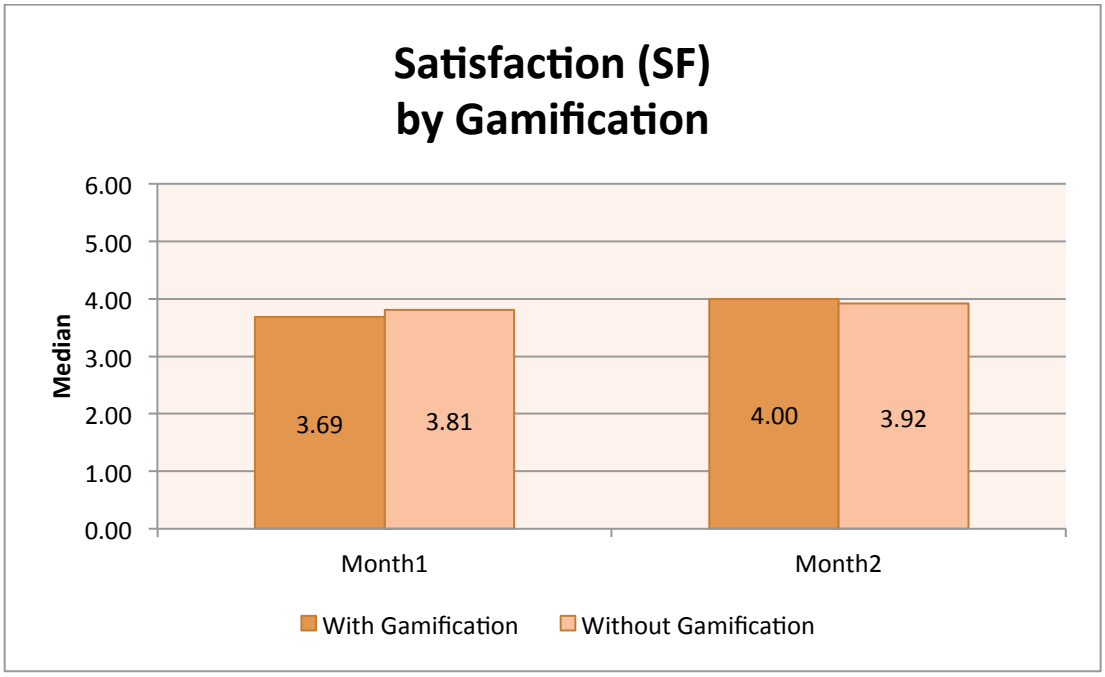

Figure 40. Median value changes of satisfaction by gamification.

The Wilcoxon signed rank tests did not elicit any statistically significant increase on the satisfaction of the runners with or without gamification. The median values of the satisfaction of the runners with gamification were 3.69 in the first month and 4.00 in the second month. The median values of the satisfaction of the runners without gamification were 3.81 in the first month and 3.91 in the second month. Thus, H3c (presence of gamification will lead to a significant increase in the satisfaction of runners) was not supported. No significant differences existed in the satisfaction change score (second month minus first month) between the runners with gamification and runners without gamification, t (28) = -.04, p = .972.

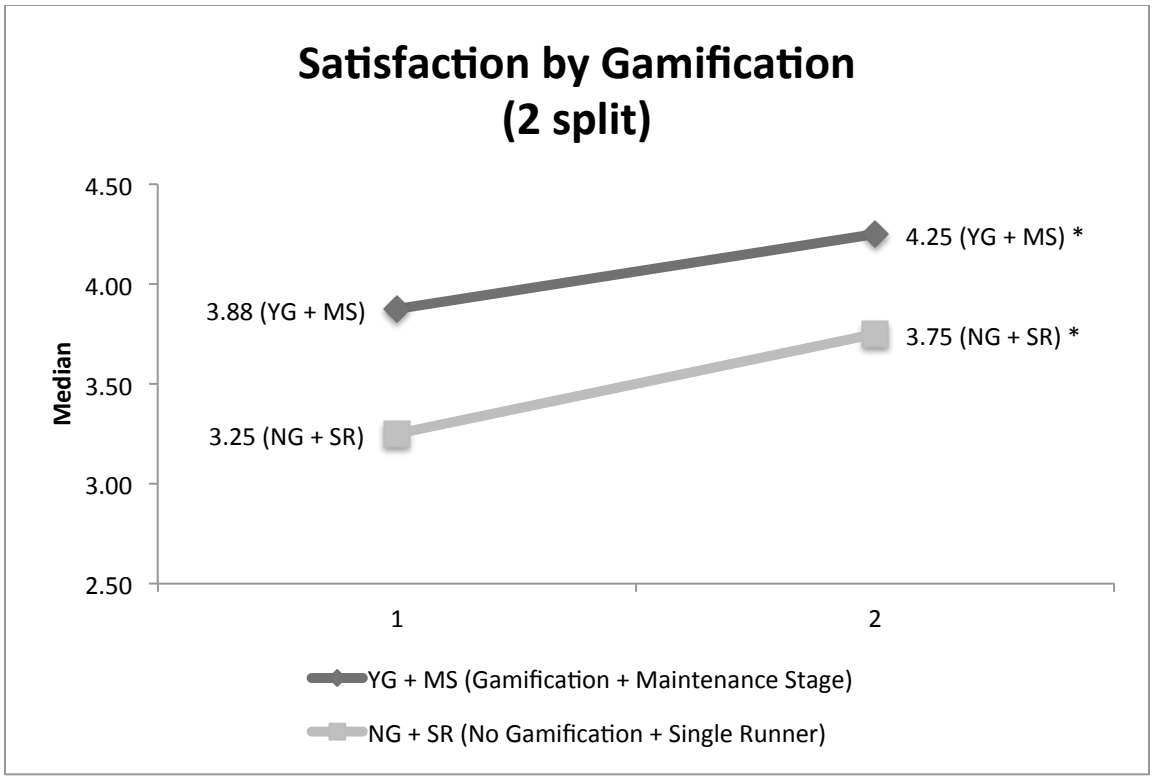

Figure 41. Split result of Wilcoxon signed test on satisfaction by gamification.

The split Wilcoxon's signed rank tests (split by gamification and runner type and split by gamification and stage of the behavior change process) revealed that the satisfaction of maintenance runners with gamification (MS + YG) was significantly higher in the second month (Mdn = 4.25) than in the first month (Mdn = 3.87), $z = 2.16$, $p = .031$. Interestingly, the satisfaction of the single runners without gamification (SR + NG) was significantly higher in the second month (Mdn = 3.75) than in the first month (Mdn = 3. 25), $z = 2.07$, $p = .038$. However, for the single runners with gamification, the team runners and action stage runners, regardless of gamification, did not show a significant increase or decrease in their satisfaction from the first month to the second month.

4.4.4. Satisfaction by Gender

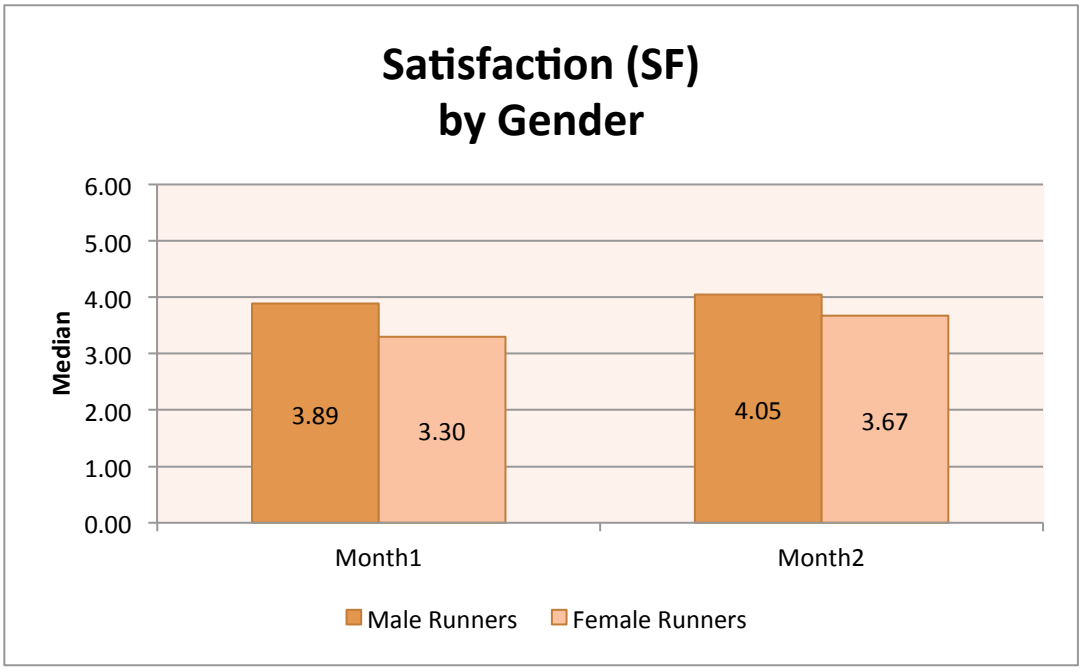

Figure 42. Median value changes of satisfaction by gender.

The median values of the satisfaction of the male runners were 3.89 in the first month and 4.05 in the second month. The median values of satisfaction of the female runners were 3.30 in the first month and 3.67 in the second month. However, the Wilcoxon signed rank tests (both one split and two split) did not elicit any statistically significant change in satisfaction for the male runners and female runners. Thus, H4c (persuasive elements will lead to a significant increase in the satisfaction of male runners) and H4g (persuasive elements will lead to a significant increase in the satisfaction of female runners) were not supported. No significant differences existed between the male and female runners' satisfaction change scores (second month minus first month), t (28) = -.68, p = .50.

4.4.5. Summary of Satisfaction

In brief, significant increases were found in single runners and runners at the maintenance stage. In the results of the two split non-parametric tests, the significant increases on satisfaction were found in the single runners when they were at the maintenance stage and when they were without gamification. For the maintenance stage runners, their satisfaction was significantly increased when they were single runners and when they were with gamification. However, as shown in the Figure 36, the satisfaction of the single runners was increased regardless of gamification, which means that the satisfaction of the single runners was (likely) not caused by the presence of gamification, but by other factors. Possible reasons are discussed in section 5.3. Regarding gender, I did not find any significant increase or decrease on satisfaction by gender.

4.5. Number of Running Activities

The number of running activities at the end of each month was obtained in order to investigate the degree to which the participants were motivated by the application as it was related to the actual number of running activities they performed. The measured data was automatically collected in the HamkeRun application when the participants performed running activities. Due to the collected data type (ratio scale) and small sample size, non-parametric Wilcoxon's signed rank tests were employed. However, the Wilcoxon's signed rank tests (both one split and two split among four between-subject factors: runner type, stage of behavior change, gamification and gender) did not show any statistically significant changes in the number of running activities from the first month to the second month. It was not possible to compare the number of running activities during use of the HamkeRun application with the pre-existing amount of running activities

because the initial surveys did not request this information at a fine-grained level of detail. Therefore, all of the hypotheses related to the number of running activities were not supported, including H1d (social elements will lead to a significant increase in the number of running activities completed by single runners), H1f (social elements will lead to a significant increase in the number of running activities completed by team runners), H2d (persuasive elements will lead to a significant increase in the number of running activities completed by runners at the maintenance stage), H2f (persuasive elements will lead to a significant increase in the number of running activities completed by runners at the action stage), H3d (presence of gamification will lead to a significant increase in the number of running activities), H4d (persuasive elements will lead to a significant increase in the number of running activities completed by male runners) and H4f (persuasive elements will lead to a significant increase in the number of running activities completed by female runners). No significant differences existed in the numbers of the running activity changes from the second month to the first month for all of the groups (single runners and team runners, $t(28) = -.74$, $p = .469$; runners at the action stages and runners at the maintenance stage, $t(28) = -1.70$, $p = .10$; runners with gamification and runners without gamification, $t(28) = 1.19$, $p = .243$; male runners and female runners, $t(28) = 1.46$, $p = .157$).

4.6. Total Number of Running Activities

As the results of the non-parametric Wilcoxon's signed rank tests on the number of running activities across the two months did not provide any statistical significance, an additional non-parametric test was conducted, as an exploratory analysis, on the total

number of running activities. This test summed the first and second months to see the direct effect of the application on the total number of actual running activities by the participants. Table 12 displays the summarized results of the Mann-Whitney tests.

Table 12. A summary of Mann-Whitney tests on total number of running activity.

Between subject factor	***U***	***W***	***z***	**Sig. Value**
Runner Type	109.5	229.5	-0.13	.775
Stage of Behavior Change	**22.5**	**142.5**	**-3.74**	**.000**
Gamification	**45.0**	**123.0**	**-2.67**	**.010**
Gender	89.0	279.0	-0.67	.641

The Mann-Whitney tests revealed significant differences in the total numbers of running activities by runners in the stage of behavior change and gamification between-subject factors. Namely, the total number of running activities by runners at the maintenance stages (Mdn = 20.00) was significantly higher than those activities of the runners at the action stage (Mdn = 9.00). Furthermore, the total number of running activities by runners with gamification (Mdn = 16.00) was significantly higher than those activities of the runners without gamification (Mdn = 8.00).

To see the more detailed significances, each group was split by runner type, stage of the behavior change process, gamification and gender. The results of the split Mann-Whitney tests showed that the most significant results were found in the between-subject factors of the stage of the behavior change process and gamification.

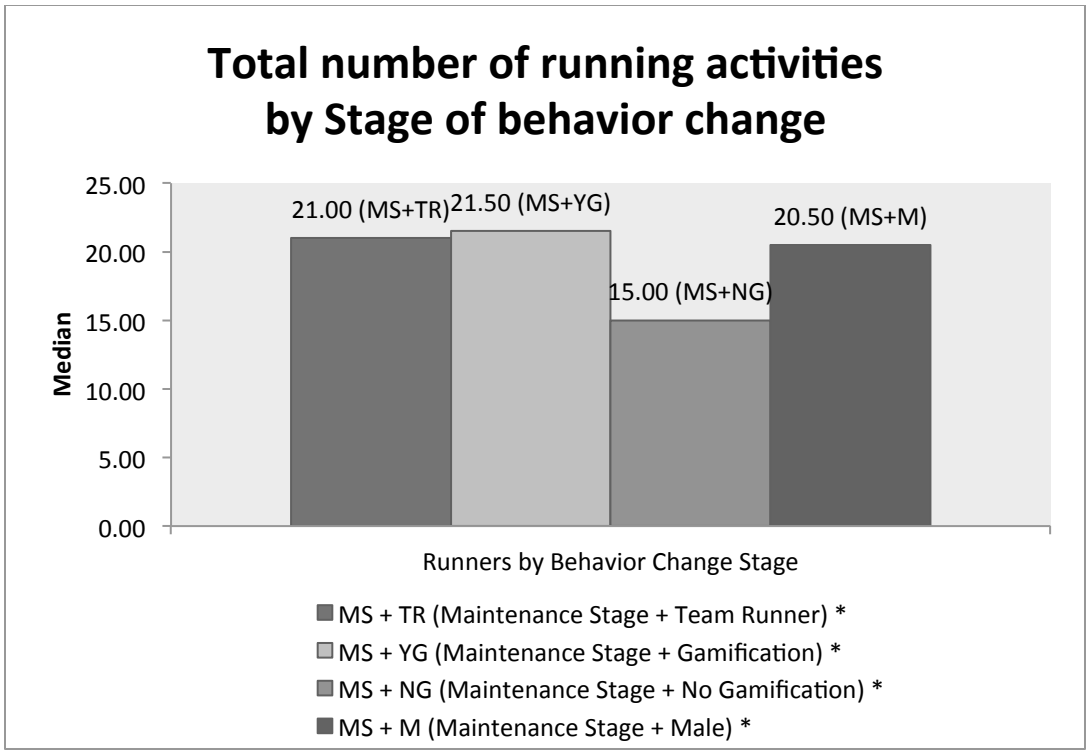

Figure 43. Split result of Mann-Whitney tests on the total number of running activities by behavior change stage

As shown in Figure 43, the total number of running activities by team runners at the maintenance stage (Mdn = 21.00) was significantly higher than the total number of running activities by team runners at the action stage (Mdn = 8.00). The same held true for the maintenance stage runners, except for the female runners (that is, the maintenance stage runners with and without gamification and the male runners at the maintenance stage). In detail, the number of running activities by the maintenance stage runners with gamification (Mdn = 21.50) was significantly higher than the number of running activities by the action stage runners with gamification (Mdn = 12.50). The total number of running activities by the maintenance stage runners without gamification (Mdn = 15.00) was significantly higher than the total number of running activities by the action stage runners without gamification (Mdn = 7.00). Also, the total number of running

activities by the male runners at the maintenance stage (Mdn = 20.5) was significantly higher than the total number of running activities by the male runners at the action stage (Mdn = 8.00). These data helped to illustrate the activity level differences among the runners at different stages.

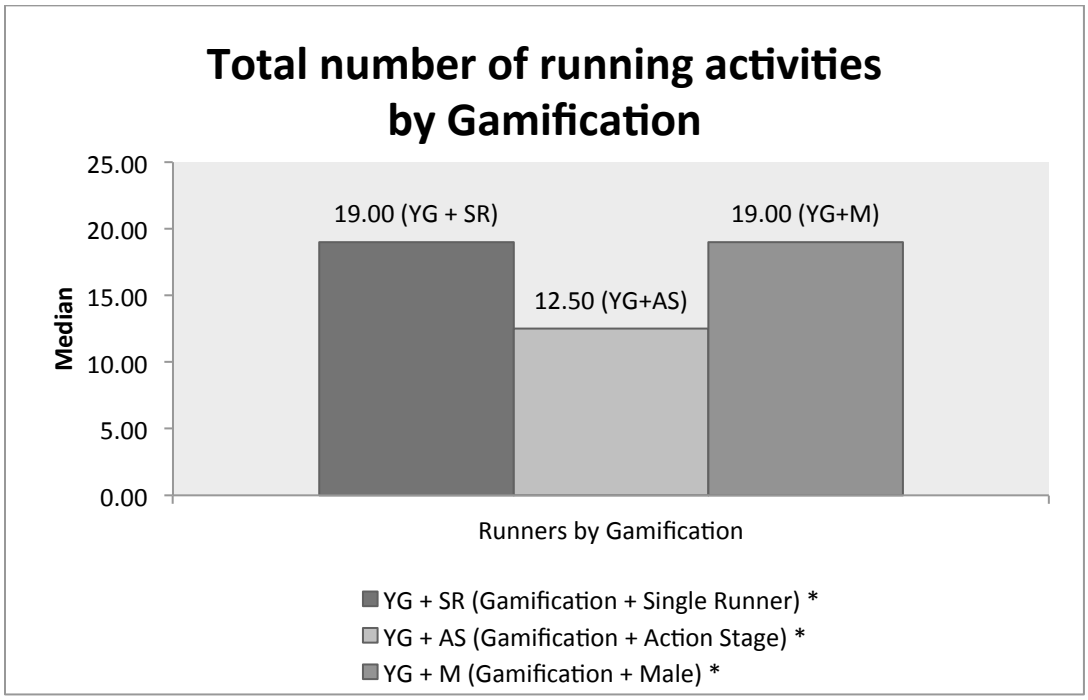

Figure 44. Split result of Mann-Whitney tests on the total number of running activities by gamification

In the gamification between-subject factor, the significant results were found when the runners were with gamification. The total number of running activities by the single runners with gamification (Mdn = 19.00) was significantly higher than the total number of running activities by the single runners without gamification (Mdn = 8.50). The total number of running activities by the action stage runners with gamification (Mdn = 12.50) was significantly higher than the total number of running activities by the action stage runners without gamification (Mdn = 7.00). Finally, the total number of running

activities by the male runners with gamification (Mdn = 19.00) was significantly higher than the total number of running activities by the male runners without gamification (Mdn = 8.00).

To sum up, the total number of running activities was significantly influenced by the runner's stage of the behavior change process and the existence of gamification. Significant increases in the total number of running activities were found in the maintenance stage runners, especially when they were team runners and male in gender. The existence of gamification was not a main effect of the significant increase for the maintenance stage runners. However, the existence of gamification showed significant increases in the total number of running activities. That is, with gamification, the total numbers of running activities of the single runners, runners at the action stage and male runners were significantly increased.

4.7. Changes of the Number of Running Activities

Since the results of the non-parametric Wilcoxon's signed rank on the number of running activities across the two months did not provide any statistical significance, as an exploratory analysis, changes in the running activity were examined using dependent samples t-tests in order to maximize power, expressed as a percentage change compared to the baseline number of runs per month (determined by multiplying the self-reported weekly run frequency from the initial survey by four). This measure helped to show whether the use of the HamkeRun application over the short- (one month) and long-term (two months) changed the participants' running frequency from their individual baseline levels by a statistically significant amount. However, the results of the dependent samples

t-test on the number of the running activity changes did not show any statistically significant differences. Table 13 displays the summarized results.

Table 13. A summary of dependent samples t-test results on the number of running activity changes

Between subject factor	Split by	*N*	*T*	Sig. Value
Runner Type	Single Runner	15	0.56	0.582
Runner Type	Team Runner	15	-0.52	0.610
Stage of Behavior Change	Action Stage	15	1.68	0.115
Stage of Behavior Change	Maintenance Stage	15	-1.05	0.310
Gamification	With Gamification	18	-0.79	0.438
Gamification	Without Gamification	12	1.04	0.319
Gender	Male	19	-0.98	0.338
Gender	Female	11	1.13	0.284

Table 14 shows the results of the split dependent samples t-tests in combinations with the four between-subject factors: runner type, stage of behavior change, gamification and gender. The purpose of these tests is to explore the potential differences in the subgroups that might have been obscured in the larger group analyses. Generally, the participants' running patterns did not change significantly despite the use of the HamkeRun application, except for two groups: the female single runner group (SR+F) and team runners at the action stage (TR+AS). The team runners at the action stage showed significant decreases in the number of running activities, t (7) = 3.13, p = .017. Although the female single runners showed a significant increase in the number of running activities, t (3) = 4.70, p = .018, this change is questionable due to the very small sample size (N=4).

Table 14. A summary of split dependent samples t-test results on the number of running activity changes

	Split by		*N*	*T*	Sig.
Runner type x Stage of behavior change	Single Runner	Action Stage	7	-0.19	.859
	Single Runner	Maintenance Stage	8	0.84	.433
	Team Runner	**Action Stage**	**8**	**3.13**	**.017**
	Team Runner	Maintenance Stage	7	-1.92	.104
Runner type x Gamification	Single Runner	Gamification	9	-0.54	.602
	Single Runner	No Gamification	6	2.42	.060
	Team Runner	Gamification	9	-0.58	.575
	Team Runner	No Gamification	6	0.00	1.00
Runner type x Gender	Single Runner	Male	11	-0.54	.603
	Single Runner	**Female**	**4**	**4.70**	**.018**
	Team Runner	Male	8	-0.80	.451
	Team Runner	Female	7	0.22	.836
Stage of behavior change x Gamification	Action Stage	Gamification	8	0.48	.644
	Action Stage	No Gamification	7	2.20	.070
	Maintenance Stage	Gamification	10	-1.10	.299
	Maintenance Stage	No Gamification	5	-0.14	.898
Stage of behavior change x Gender	Action Stage	Male	11	0.77	.461
	Action Stage	Female	4	2.19	.116
	Maintenance Stage	Male	8	-1.65	.143
	Maintenance Stage	Female	7	0.33	.751
Gamification x Gender	Gamification	Male	11	-1.71	.118
	Gamification	Female	8	0.77	.474
	No Gamification	Male	7	0.64	.544
	No Gamification	Female	4	0.93	.423

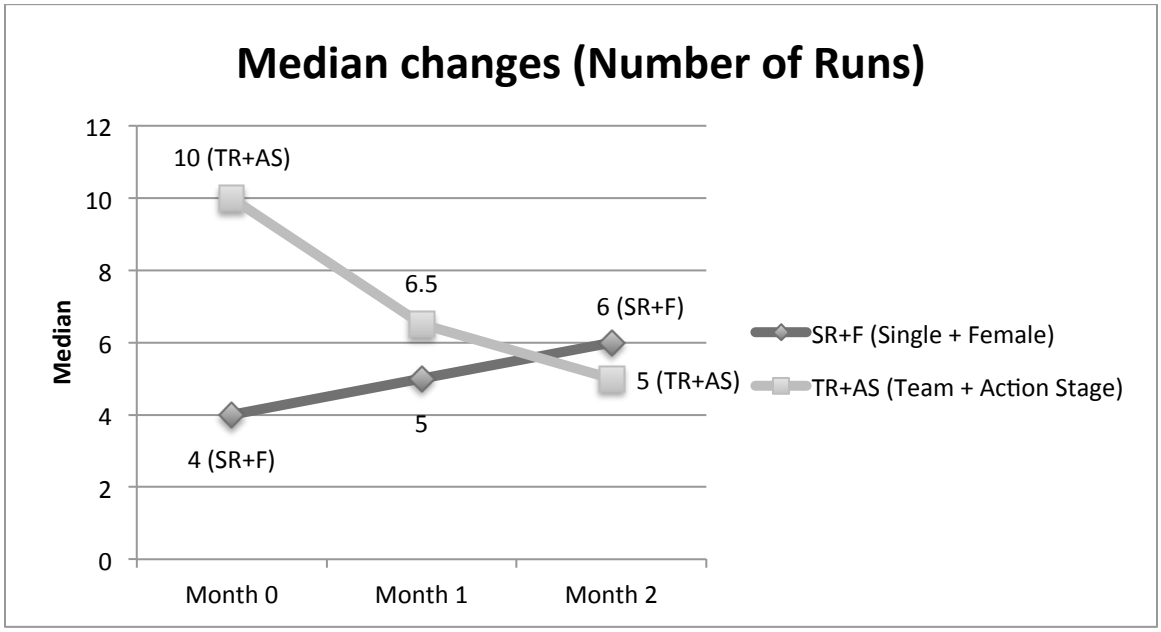

Figure 45. Median changes of the number of running activity

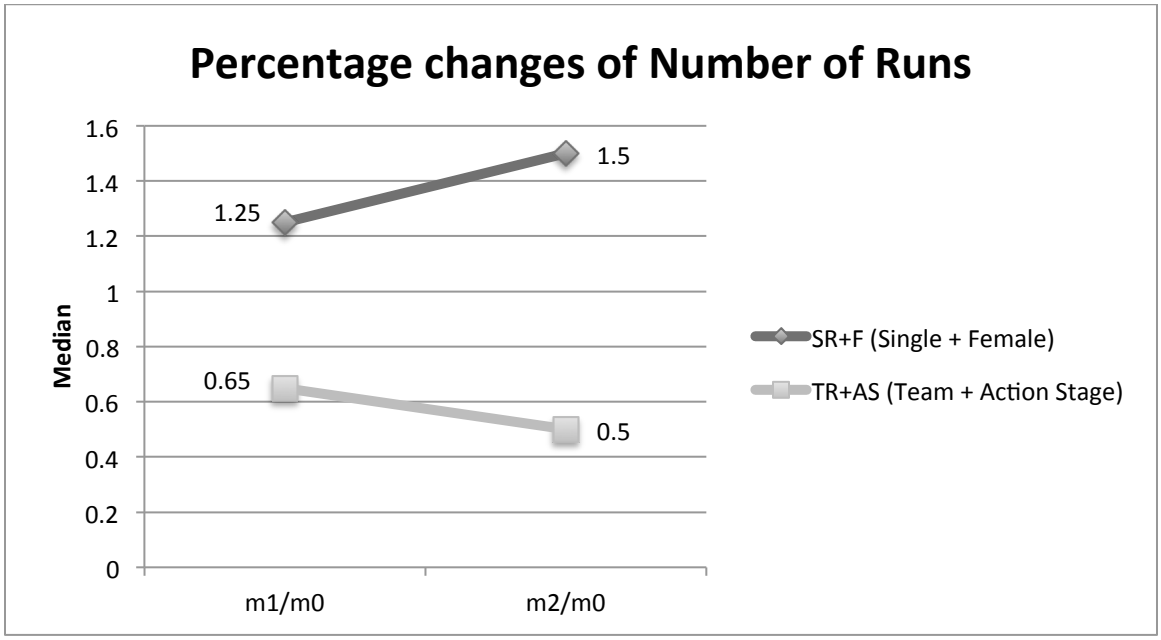

Figure 46. Percentage changes of the number of running activity

4.8. Satisfaction with the Concepts of Motivational Elements

The participants' satisfaction with the individual concepts of information visualization, gamification and social competition (or social cooperation) was also measured to see the degree to which the participants were satisfied with each concept as a motivational element provided in the HamkeRun application. Similar to the overall satisfaction, the measured data was collected through seven Likert scale-based questions (0: "Strongly Disagree" to 6: "Strongly Agree"). Due to the collected data type (ordinal scale) and small sample size, non-parametric Wilcoxon's signed rank tests were employed.

Table 15. A summary of Wilcoxon signed tests on satisfaction with the concept of gamification

Between subject factor	**Split by**	***N***	***U***	***Z***	**Sig. Value**
Runner Type	Single Runner	15	36.00	0.92	.359
	Team Runner	**15**	**33.00**	**2.16**	**.031**
Stage of Behavior Change	Action Stage	15	29.00	1.61	.107
	Maintenance Stage	15	41.50	1.48	.138
Gamification	With Gamification	18	46.50	1.25	.210
	Without Gamification	12	25.00	1.93	.054
Gender	**Male**	**19**	**67.50**	**2.31**	**.021**
	Female	11	12.00	0.33	.739

4.8.1. Satisfaction with the Concept of Information Visualization

The Wilcoxon's signed rank tests (split among four between-subject factors: runner type, stage of behavior change, gamification, and gender) did not show any statistically significant changes in satisfaction on the concept of information visualization from the first month to the second month, although the mean value of each month was above the neutral point (three of the seven point scale).

4.8.2. Satisfaction with the Concept of Gamification

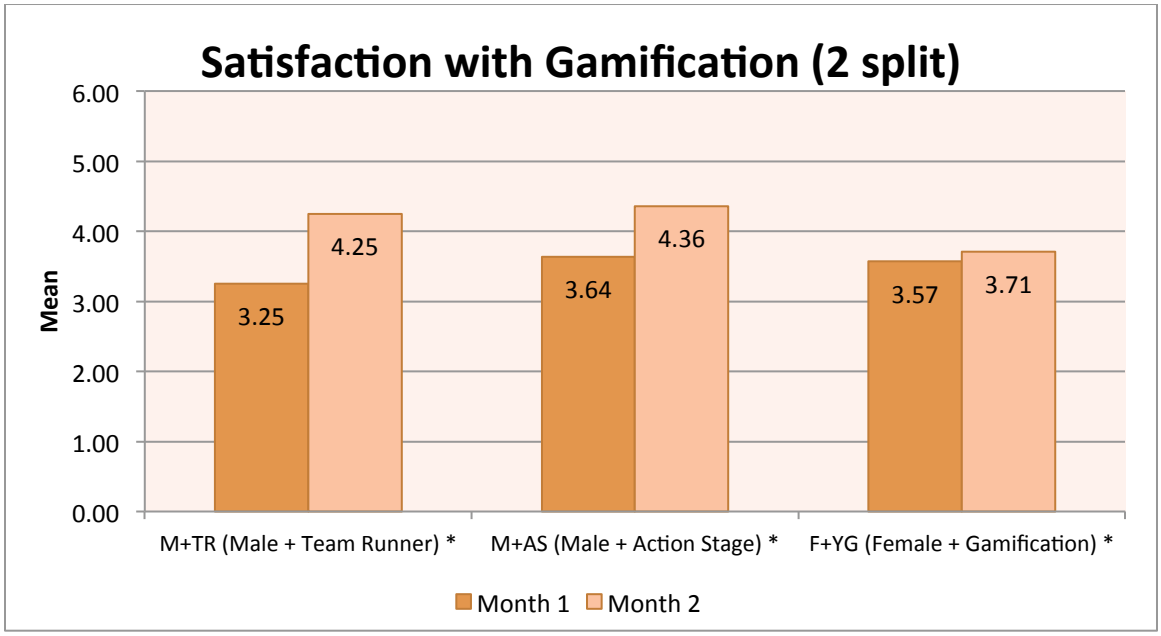

Figure 47. Median value changes of satisfaction with the concept of gamification.

A Wilcoxon's signed rank test revealed (Table 15) that the satisfaction of the team runners was significantly higher at the end of the second month (Mdn = 4.00; M=4.13) than at the end of the first month (Mdn = 4.00; M=3.47). Also, the male runners showed significant increases from the first month (M=3.61) to the second month (M = 4.26).

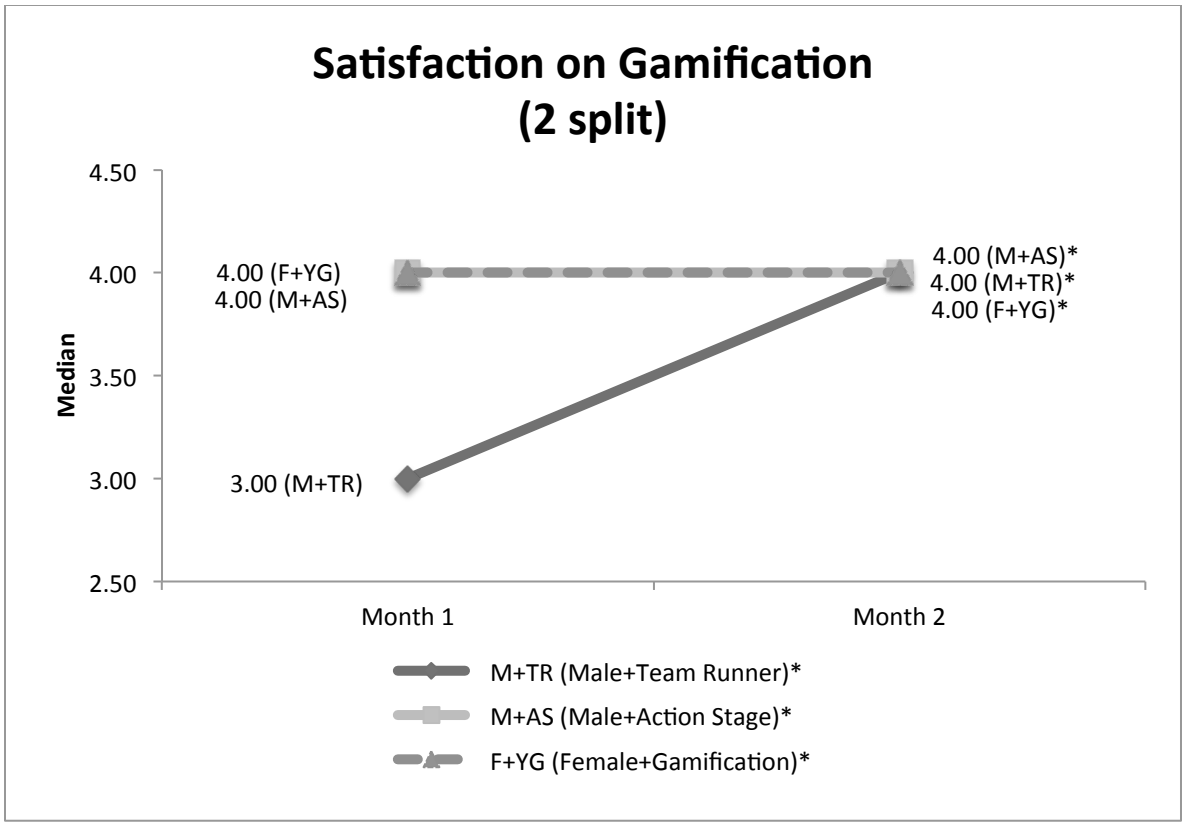

Figure 48. Split result of Wilcoxon signed test on satisfaction with the concept of gamification.

The results of the split Wilcoxon's signed rank tests revealed a hidden significance as the satisfaction of the male team runners (TR+M) was significantly higher in the second month (Mdn = 4.00; M=4.36) than in the first month (Mdn = 4.00; M=3.64, and the satisfaction of the male runners at the action stage (M+AS) was also significantly higher in the second month (Mdn = 4.00; M=4.36) than in the first month (Mdn = 4.00; M=3.64). Also, female runners with gamification (F+YG) showed a significant increase in satisfaction from the first month (Mdn = 4.00; M=3.69) to the second month (Mdn = 4.00; M=4.09).

4.8.3. Satisfaction with the Concept of Social Competition (Cooperation)

No statistically significant change in the participants' satisfaction with the concept of social competition (social cooperation) from the first month to the second month was found in the Wilcoxon's signed rank tests results (both one split and two split among the four between-subject factors: runner type, stage of behavior change, gamification and gender). Also, the mean value for each month was above the neutral point (three of the seven point scale).

CHAPTER 5: DISCUSSION

On the whole, the HamkeRun application provided quite positive effects on internal motivation and a moderately positive levels of external motivation, while it showed selectively positive effects on satisfaction and the total number of running activities recorded depending on runner type, stage of behavior change, gamification and gender. When the changes in the median values of the between-subject factors were examined, the results also supported these conclusions. This chapter presents the theoretical framework revisited, main effects of the between-subject factors, findings from the final interview and design guidelines for the persuasive application developers and designers.

5.1. Theoretical Framework Revisited.

In order to interpret the results of the data analysis and explain the phenomena that the runners have shown during the study, the theoretical framework was repeatedly revisited and refined. As shown in Figure 5 in Chapter 3, the traditional TTM in the exercise domain (Prochaska & Marcus, 1994) stated that the internal motivation of the runners at the action stage dropped and then escalated again at some point during the action phase, while their external motivation escalated and then started to drop as they repeated activities. For the maintenance runners, their external motivation dropped, while their internal motivation significantly escalated.

In the results of the HamkeRun study, the runners at the maintenance stage showed an increasing trend in regard to their internal motivation from the beginning of

[1] SR (Single Runner), TR (Team Runner), AS (Action Stage Runner), MS (Maintenance Stage Runner)

the study to the second month. These results are consistent with the TTM. Slightly different from the maintenance stage runners, the action stage runners showed increases in their internal motivation from the beginning to the first month, but their motivation slightly decreased in the second month. However, because motivation levels of the action stage runners at the beginning of the HamkeRun study does not mean that their motivation levels are at the starting point in the action stage, this can be interpreted that most action stage runners recruited in the HamkeRun study were located in the middle of the action stage (an orange area as shown in Figure 49).

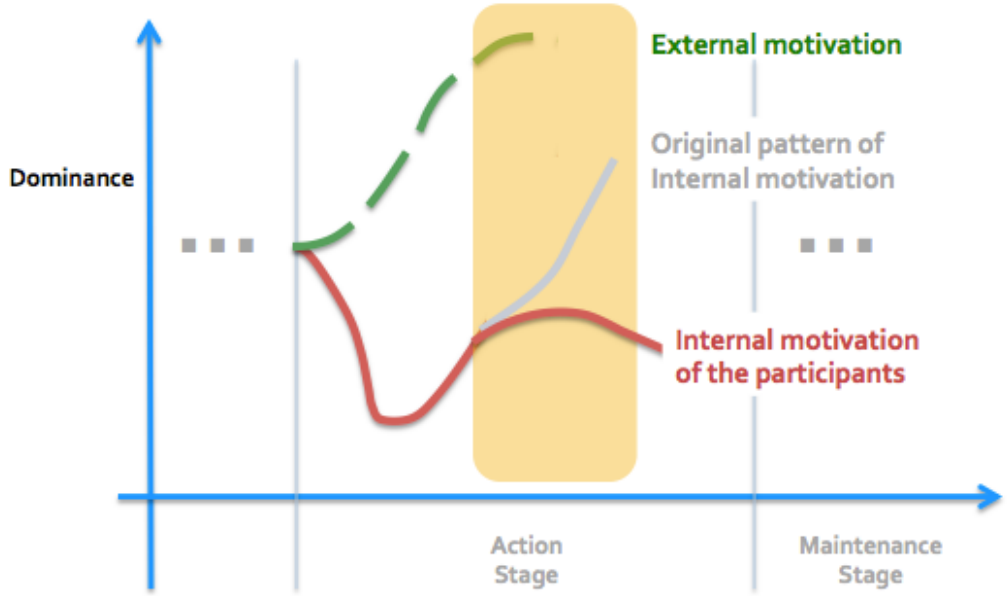

Figure 49. The recruited action stage runners in the transtheretical Model.

One possible reason for the decreased internal motivation of the action stage runners is their low frequency of use of the HamkeRun application due to external factors, such as midterm projects and exams for the student participants (more details are described in section 5.3.) If this assumption of the action stage runners in the HamkeRun study and the reason for the slight decrease in their internal motivation are accepted, then

the trend on internal motivation for the action stage runners would be consistent with the TTM model.

With regard to external motivation (motivational effect of the HamkeRun application), the action stage runners demonstrated a decreasing pattern. The app's external motivation on these runners decreased from the first month to the second month, which is consistent with the TTM model. However, for the maintenance stage runners, the app's external motivation effect increased significantly from the first month to the second month, which is different from the TTM model and meets the initial objective of the study. This suggests that the external motivation on the maintenance stage runners can be increased externally by motivational elements in persuasive systems.

Next, the HamkeRun application embedded the spark trigger and signal trigger, which are the two of the three types of trigger from the FBM (Fogg, 2009). The model states that the spark trigger is something that makes people move forward to a target behavior, such as text that highlights a fear or a video that inspires hope. This trigger type is effective when people have low levels of motivation. The signal trigger serves simply as a reminder and works best when people have both sufficient motivation and ability. It is suggested that it should be used in a well-timed manner, while avoiding becoming annoying or condescending. Based on the results of the data analysis and the user comments, this signal trigger should be more tailored depending upon the different stages of the runners whose expectations about the reminder are different.

When analyzing the runners' comments about the question asking about external factors, which made and will make them perform actual running activities, some of the runners considered the reminder to be an effective trigger. The analysis showed that the

maintenance stage runners, on the one hand, tended to provide fewer comments about the reminder and expressed interest in a reminder system telling them their activity schedules and health status measures, such as BMI score and weight. These comments are as follows: "Reminder of intense workout schedule" (P8, [1] SR+MS), "The app may benefit if it had a calendar with reminders that the user could input a jogging routine. The calendar visual with the data visual might keep the user on track." (P30, TR+MS) and "Push myself that I need to exercise for weight control. It would be helpful if somebody or the app tells (warns) me whether my BMI score or any health score is in the danger zone or in the safe (healthy) zone" (P15, SR+MS).

On the other hand, the action stage runners tended to provide more feedback about the reminder and wanted more customized content and stronger reinforcement for the actual activity. The comments about the reminder as a signal trigger included: "A reminder of benefits" (P4, SR+AS), "Step-by-step guidance in the app" (P23, TR+AS), "Guidance by actual person, friends, or the application" (P6, SR+AS), "Someone or anything pushes me to run" (P18, TR+AS), "Someone who can run with me or something which makes me want to move" (P18, TR+AS) and "More dynamic notifications from the app when there are any significant changes in scores or positions in the leaderboards. If the app could sense the weather around my location (home) and suggest if this could be a good time go running based on weather predictions and temperature preferences, set by the user" (P7, SR+AS).

Although it is not generalizable mainly due to the insufficient number of comments about the reminder, the maintenance stage runners tended to focus more on the reminders communicating the current statuses of their bodies, health and running levels

because they already possess high motivation to perform a target behavior and do not need a strong trigger. However, the action stage runners tended to focus more on the reminders (a) telling the participant the benefits of performing the target behavior with step-by-step guidance, (b) reinforcing performance and (c) having more dynamic forms and various contents related to running.

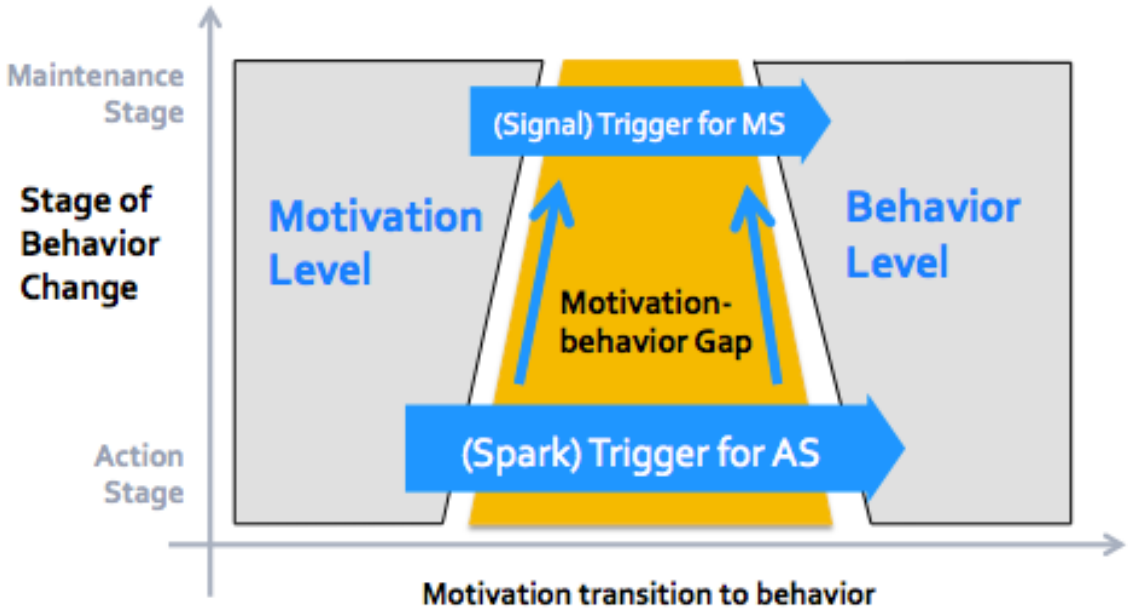

Figure 50. A motivation-behavior transition model according to stage of behavior change showing motivation-behavior gap

Therefore, a new, simple conceptual model of trigger supplemental to the FBM in the running context is proposed using two different views. In the first view (Figure 50), the proposed model shows a relationship between the trigger and motivation transition for different stages of behavior change. The vertical axis indicates the stages of behavior change and the horizontal axis indicates the transition from the motivation level to the behavior level.

The model shows that a gap exists between the motivation level and actual behavior level and suggests that a different trigger type would facilitate the transition from the motivation level to the behavior level. The main assumption of this model is that the size of the gap is different according to the participants' stages of behavior change, that is, the size of the gap for the action stage runners is bigger than the gap size for the maintenance stage runners. This difference means that the action stage runners need relatively stronger and a more variety of the types of triggers when compared to the maintenance stage runners. As the stage of behavior change progresses to the maintenance stage, the gap size gets smaller and the runners need a relatively smaller and less complex trigger.

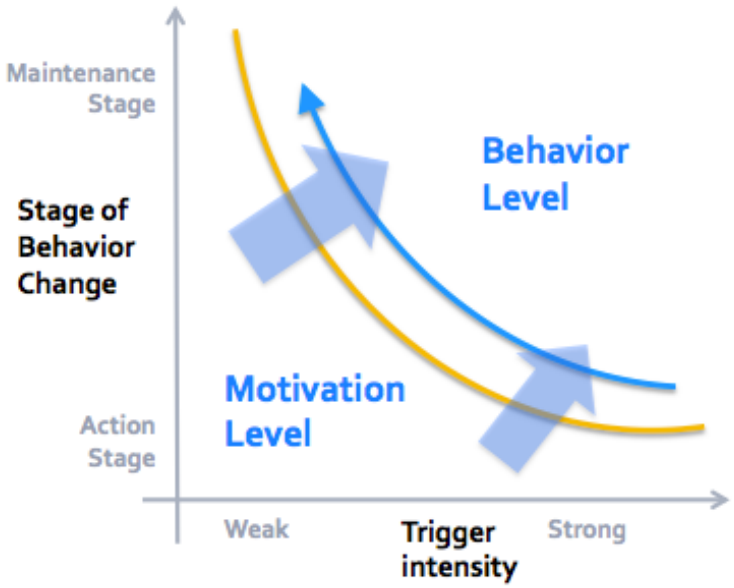

Figure 51. A motivation-behavior transition model showing a relationship between stage of behavior change and trigger intensity

The second view of the proposed model (Figure 51) shows the relationship between the trigger intensity and the target behavior according to the different stages of behavior change. In this context, the 'intensity' describes the intensity of the trigger for each stage of behavior change, such as in its representation, frequency, persuasive power, tones and level of personalization (or customization). Therefore, to perform a target behavior (running activity in this context), the action stage runners require relatively stronger triggers in their intensity to reach to the desired behavior level.

5.2. Motivational Effect of Between-subject Factors

5.2.1. Differences Between Runner Types

The concept of social grouping (or social support) is considered to be a powerful and effective motivational element to stimulate physical activities. Positive beliefs exist about the use of social support in regard to increasing physical activity through online social network services despite insufficient efficacy (Cavallo et al., 2012; Wong et al., 2004). For this reason, the value of the dependent variables—external motivation (motivational effect of the HamkeRun application), internal motivation, satisfaction and number of actual running activities of the participants—were empirically examined for each runner type (single runner / team runner). In general, the single runner type showed significant increases in their external motivation, internal motivation and satisfaction, while the team runner type showed significant increases only in internal motivation.

Specifically, for external motivation, the app significantly increased the single runners' motivation (external motivation) from the first month to the end of the second

month. Significant increases in external motivation were also found in the results combined with the maintenance stage (SR+MS), gamification (SR+YG) and male runners (SR+M). However, the app's motivational effect (external motivation) was not significant for the team runners.

For internal motivation, both the single and team runners showed significant increases from the beginning of the study to the second month. The analyses also showed significant increases in internal motivation for the single runners at the action stage (SR+MS), single runners with gamification (SR+YG), single runners without gamification (SR+NG), male single runners (SR+M), team runners at the maintenance stage (TR+MS), team runners with gamification (TR+YG) and female team runners (TR+F). Regarding satisfaction, the single runners showed a significant increase from the first month to the second month. The results of the tests combined with the maintenance stage (SR+MS) and gamification (SR+YG and SR+NG) also supported the effect of the single runner type on the increase of satisfaction. However, the runner type did not have any significant effect on the number of running activities.

The possible reasons for these findings seem to be mainly due to social grouping with unknown others and the contextual characteristic of a running activity. Namely, each team was composed of unknown others as running mates who were only able to see their running data in visualized representations. Therefore, the team composition could not assist in motivational increases of the team members. Next, running is mostly an individual sport; runners usually motivate themselves to perform running activities. Single runners tended to be less influenced by others and focused more on themselves, so

the app provided more motivation (external motivation) for these runners. When comparing the comments between the single and team runners, this becomes apparent.

Both the single and team runners, in general, considered social grouping (or social competition) as a positive motivational element: “Competition motivates me” (P20, TR+AS), “Although I prefer running alone, it's enjoyable to see when I got my ranking up in the leader board” (P9, SR+MS), “Competing with myself or teammates is the one of the best features in the application. Because my team and I were able to see my data and others' data, we all could motivate each other to run more even though we do not run together simultaneously” (P16, TR+AS) and “This feature is fantastic because even when I am running alone, I know there are others running with me through this app” (P30, TR+MS).

However, some of the single runners expressed indifference about the social competition: “I am not interested in competing with others” (P10, SR+MS), “I consider running to be a personal sport, so competing with others did not motivate me to run more” (P15, SR+MS) and “Little extra motivation, especially since I run alone most of the time” (P24, TR+MS).

One team runner specifically complained about the social competition with unknown others: “I am not much comfortable competing with others or being defeated by someone I don’t know” (P23, TR+AS).

These data indicate that having social support on its own does not produce significant increases in motivation, satisfaction or number of running activities. Social support (or social grouping) with unknown others, even on the same team, should be carefully considered for a successful motivational element. It is, however, worth noting

that, although the team runners did not show a significant increase in, most of their external motivation (the app's motivational effect) was still above the neutral point of the seven point scale, from 0 to 6, and increased from the first month to the second month. Further investigations seem to be of interest in regard to identifying the significant effects of a social group among known people, a social group among unknown others and the significant differences between these groups.

5.2.2. Effect of Stage of Behavior Change

Runners at different stages of behavior change have different motivation levels and react to motivational elements differently. In this study, the HamkeRun application helped boost runners at the maintenance stage in regard to the dependent variables more than runners at the action stage. The results of the data analyses demonstrated that the maintenance stage runners showed significant increases in external motivation, internal motivation, satisfaction and the total number of running activities performed, while significant increases for the action stage runners were only found in internal motivation.

In terms of the app's motivational effect (external motivation), the maintenance stage runners showed significant increases from the first month to the second month. The split results combined with runner type (MS+SR), gamification (MS+YG) and gender (MS+F) also supported this result. However, unexpectedly, the opposite was true for the female runners at the action stage (AS+F), who showed significant decreases.

For internal motivation, the runners at both the maintenance and action stages showed significant increases from the beginning of the study to the end of the second month. Significant increases were found for the team runners at the maintenance stage

(TR+MS), maintenance stage runners with gamification (MS+YG), female runners at the maintenance stage, single runners at the action stage (SR+AS), action stage runners with gamification (AS+YG) and male runners at the action stage (SR+M).

For satisfaction, only the runners at the maintenance stage showed a significant increase in satisfaction from the first month to the second month. A significant increase in satisfaction was only found for the single runners at the maintenance stage (SR+MS). Stage of behavior change greatly influenced the total number of running activities. Team runners at the maintenance stage (MS+TR), maintenance stage runners with gamification (MS+YG), maintenance stage runners without gamification (MS+NG) and male runners at the maintenance stage (MS+M) showed significant increase in the total numbers of running activities during the study.

It seems that the motivational elements in the HamkeRun application were not very effective in producing significant increases until they passed some threshold in combination with the runners' motivation and behavior levels. In other words, runners at the maintenance stage were more influenced by the motivational elements in the HamkeRun because their levels of both motivation and behavior were above this threshold point (Figure 52). However, the effect disappeared for the action stage runners because their levels were below the threshold point. Therefore, this result suggests further investigations in ways by which action stage runners can quickly reach the threshold point.

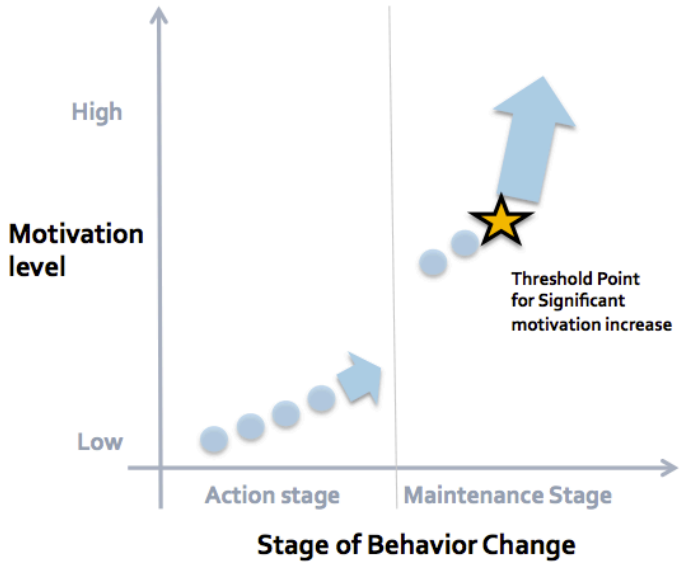

Figure 52. A simple model showing a threshold point for significant motivational increase according to motivation level

5.2.3. Effect of Gamification

The concept of gamification has been also assumed to be one of the most powerful and effective motivational elements with representative advantages, such as enjoyment, positive feelings of achievement and possible user engagement in physical activity (Froehlich, 2009; Reeves & Read, 2009; Antin & Churchill, 2011; Deterding et al., 2011). Therefore, the gamification concept was employed and empirically tested to evaluate its effectiveness in the running context. As intended, the concept of gamification greatly influenced increases in external motivation, internal motivation and total number of running activities.

For the app's motivational effect (external motivation), the runners with gamification showed significant increases from the first month to the second month. The single runners with gamification (YG+SR), maintenance stage runners with gamification (YG+MS) and male runners with gamification (YG+M) also showed significant increases

in external motivation. For internal motivation, the runners with gamification showed significant increases from the beginning of the study to the second month. The single runners with gamification (YG+SR), team runners with gamification (YG+TR), action stage runners with gamification (YG+AS) and maintenance stage runners with gamification (YG+MS) showed significant increases in external motivation. Interestingly, the single runners without gamification (SR+NG) showed an increase in internal motivation. One possible reason for this result seems to be that single runners were not much influenced by a lack of gamification. For satisfaction, the single runners with gamification (SR+MS) and single runners without gamification (SR+NG) showed a significant increase in satisfaction from the first month to the second month.

However, not all of the runners were satisfied with the elements of the gamification, mainly due to their higher expectations toward the games, fewer controls over the gamification characters and technical issues. In addition, some of the runners, especially at the maintenance stage, were not much affected by the gamification elements and stated, for sample, "I do not feel particularly motivated by games. Although the game aspect may be helpful for some people, it did not increase or decrease my level of interest in the app or in running" (P26, TR+MS). More detailed comments are described in section 5.3.

For the total number of running activities, the runners with gamification showed significant increases from the beginning to the end of the study. Significant increases in the total number of running activities were found for the runners with gamification, especially when they were single runners, at the action stage and male in gender. Furthermore, two runners at the action stage mentioned gamification as one of the ways

that the application helped them engage in running: “For me, other apps in the app store pushed people to run more and more to some extent, but, this app didn't push much. This game feature seemed to work like that indirectly” (P5, SR+AS) and “[The] game character lowered the barrier to use the application and enabled to stick to my data (my character) to some extent” (P23, TR+AS).

The results of these increases were not much different from the initial expectations. The possible reasons seem to be rather straightforward according to the participants’ comments on gamification. Some of the runners mentioned the achievements, engagement and look-and-feel as motivational elements: “Like the concept. More engaged” (P13, SR+MS), “Overall UI of the game features was attractive to see and feel. The achievement checking system is fun to try” (P11, SR+ MS) and “It gave me a feeling of level up so that I feel like I can grow up my capabilities” (P3, SR+AS).

As shown in Figure 43, the action stage runners with gamification showed a statistically significant increase in the total number of running activities. These results suggest that the trigger instantiated with the gamification elements, which was expected to narrow the motivation-behavior gap (Figure 50), was especially effective for the action stage runners. Specifically, a spark trigger type utilizing gamification can encourage runners at the action stage to perform a running activity and the signal trigger type can serve as their stage progresses to the maintenance stage. Thus, persuasive system developers and designers should utilize gamification elements as a trigger for action stage runners.

5.2.4. Effect of Gender

A number of studies have shown that gender differences exist in exercise due to certain kinematic differences, for example, females are more likely to sustain a running injury (Geraci & Brown, 2005; Taunton et al., 2002), show greater non-sagittal motion (Chumanov, Wall-Scheffler, & Heiderscheit, 2008) and show greater peak hip adduction (Ferber et al., 2003). Thus, the effect of gender was observed in order to test the existence of significant gender differences in external motivation, internal motivation, satisfaction and total number of running activities during the study.

Overall, the male runners showed significant increases in external motivation and internal motivation, while the female runners only showed significant increase in internal motivation. For external motivation (the app's motivation effect), the male runners showed a significant increase in their external motivation from the first month to the second month. The male single runners (M+SR), male runners with gamification (M+YG) and female runners at the maintenance stage (F+MS) showed significant increases in their external motivation. For internal motivation, both the male and female runners showed increases from the beginning of the study to the second month. Significant increases in internal motivation were found for the male single runners (M+SR), male single runners at the action stage (M+AS), female team runners (F+TR), and female runners at the maintenance stage (F+MS). However, gender did not significantly influence satisfaction or the total number of running activities.

Inspection of the median values revealed interesting findings. The male runners showed higher external motivation and satisfaction than the external motivation and satisfaction of the female runners (left in the Figure 53).

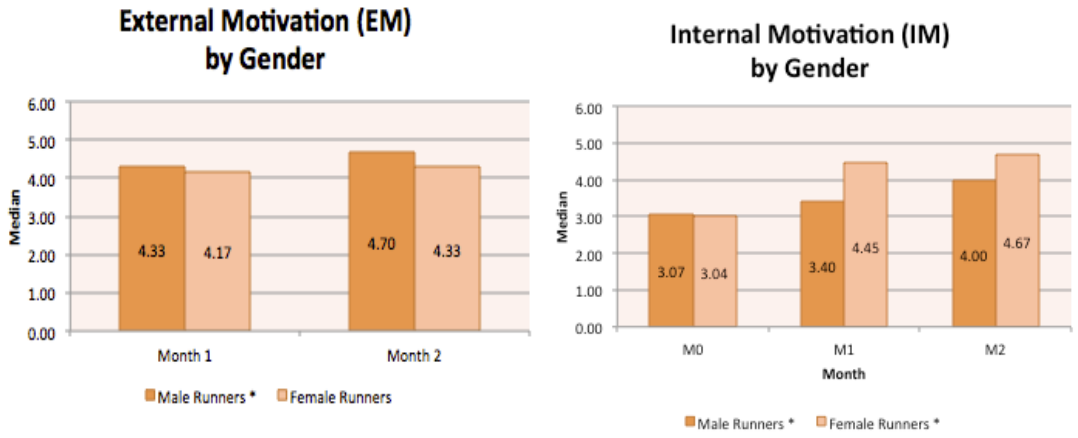

Figure 53. Median value changes of external and internal motivation by gender

However, the female runners showed higher internal motivation, with significant increases across time, than the male runners. In addition, the female runners ran slightly more than the male runners during the study (left in the Figure 54).

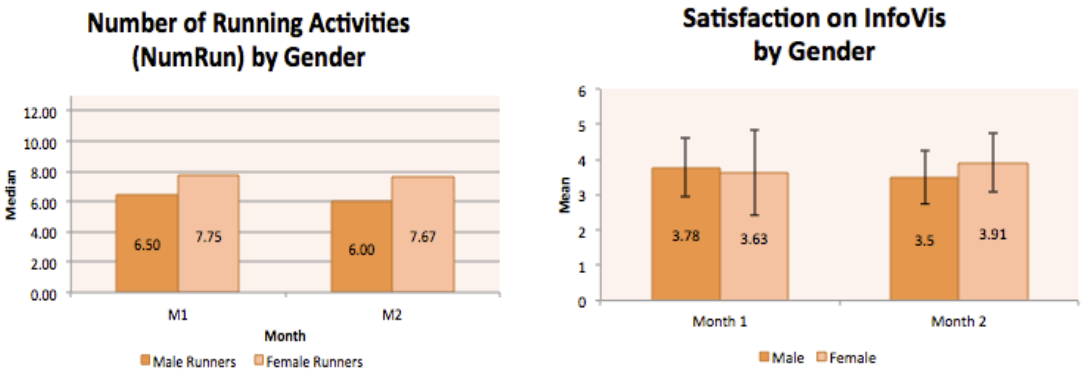

Figure 54. Median value changes of number of running activity and mean value changes of satisfaction with information visualization by gender

With regard to the participants' satisfaction with each motivational element, neither the male nor female runners showed statistically significant increases based on any of the motivational elements. However, the male runners tended to be more satisfied

with the element of gamification than the female runners and showed sharp increases in the second month. The female runners tended to be more satisfied with the element of information visualization. Initially, for the female runners, satisfaction with the element of information visualization was lower in the first month than the satisfaction of the male runners. However, in the second month, the female runners showed increased satisfaction, while the satisfaction of the male runners dropped. Regarding satisfaction with the element of social competition, no significant gender differences were found, although the satisfaction of the female runners was slightly higher than the satisfaction of the male runners. Both the male and female runners showed similar mean values and slight increases from the first month to the second month (Figure 55). This trend breaks with the assumption that males tend to be more competitive than females. The possible reasons seem to be that, first, social competition in the HamkeRun study is not the actual process of trying to win or get something, such as a prize or a higher level of success. The second reason may be that running is an individual sport, so the runners try to compete against themselves rather than against other individuals. Supporting comments include: “I am not comfortable competing with others or being defeated by someone I don’t know” (P23, TR+AS), “I consider running to be a personal sport, so competing with others did not motivate me to run more” (P15, SR+MS) and “A little extra motivation, especially since I run alone most of the time” (P24, TR+MS).

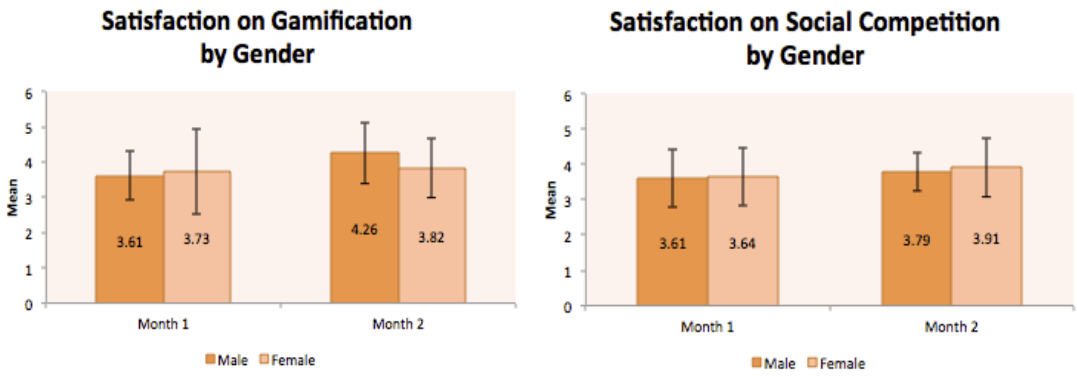

Figure 55. Mean value changes of satisfaction with gamification and social competition by gender

5.3. Analysis of the Qualitative Comments by Participants.

In the questionnaires, the participants were asked to comment on their satisfaction with each concept of information visualization, gamification, social competition (or social cooperation), external motivational factors not from the application and additional future features they would want to use as motivational elements in the next version of the application.

5.3.1. Satisfaction with Each Concept of Motivational Elements

(1) Satisfaction with Information Visualization

Overall, the participants considered the concept of the information visualization, which was provided in the application, to be positive. The satisfaction scores for the concept of information visualization were positive and increased from the first month to the second month, but not significantly. The positive comments included: "[It was] easy to view and understand my data" (P9, SR+MS), "User-friendly" (P14, SR+MS), "beautiful" (P12, SR+MS), "Intriguing" (P11, SR+MS), "[It was] easy to focus and be

absorbed" (P2, SR+AS), "It was confusing first but now it's helpful" (P21, TR+AS) and "It gave a different perspective on how to look at the data, rather than just seeing numbers" (P24, TR+MS)..

Most of these comments were consistent with the representative advantages of information visualization shown in the literature (Chittaro, 2001; Lee et al., 2006; Lau & Vande Moere, 2007; Lurie & Mason, 2007; Yi, 2008; Pfaff et al., 2010).

Interestingly, one participant (P25, TR+MS) mentioned the trackability feature of the line graph that helps the user organize and trace data movement over time: "The graphical charts made it easier to keep track of my running activities." In an extension of this statement, another participant (P8, SR+MS) mentioned, "It was easy to interpret [the] results and think [of] improvement[s]." This is also another advantage of the line graph - predictability - that enabled the user to connect the data points and predict the coming values (Tversky, Zacks, Lee, & Heiser, 2000; Kessel, 2008). This is also in line with one of the main features of information visualization: inference of information (Tversky, 2001). Another interesting comment was: "The graphs are cute. More graphs are better than many numbers. But, sometimes, I felt guilty when I saw blank spots in my chart, and fear of viewing the chart again" (P22, TR+AS).

This suggests that the concept of information visualization may serve as an effective spark trigger, which may induce users to substantiate their data into actual running activities performed.

Although most of the participants rated the concept of information visualization as positive, some wanted more interactivity and more types of information visualization: "It was good thinking to show the data through the chart, but there wasn't any

interactivity associated with it. I would like to see a more refined and a different way to visualize the data" (P17, TR+AS). One participant wanted to compare his data not only to others, but also to his previous data: "It shows my previous runs, [from] which I can easily recognize my habit nicely. It would be better if it showed more and if it [could] compare current and previous months" (P26, TR+MS).

However, not all of the participants were satisfied with the information visualization. Specifically, two participants commented: "I'm not all that interested in graphical representation of the data" (P10, SR+MS) and "It is interesting to grab my attention at first. But, I do not care much about representation type of my run, whether it's graphical or numeric" (P29, TR+MS). As these participants were at the maintenance stage, they seemed not to be persuaded by the usual representation of their activity data. Other participants complained about the limited size of the information visualization on the screen, "I expected to see more run data and deeper levels of data in detail, like comparisons of my previous data to others. Current chart size is too small" (P27, TR+MS).

There were some UI issues in visualizing the data, which were indirectly related to information visualization, but negatively affected the satisfaction of participants: "I often faced some UI issues, such as scrolling up-down the page because the charts occupied the whole width and I would often accidentally click/select them" (P7, SR+AS) and "There were some glitches in trying to see the charts. The app requires to be faster and optimized for smooth interactions" (P28, TR+MS).

(2) Satisfaction with Gamification:

In the qualitative responses, the participants also rated the concept of gamification moderately positively. The satisfaction scores on the concept of gamification increased slightly from the first month to the second month. The positive comments on gamification included "I was not bored" (P3, SR+AS), "attractive" (P16, TR+AS), "fun and exciting" (P18, TR+AS), "more engaged" (P20, TR+AS), "I like hero characters. I can be engaged in it" (P12, TR+MS) and "It also shows [the leaderboard] data beautifully and nicely. I was not bored with seeing mine and others" (P28, TR+MS). Some interesting comments included: "Game character lowered the barrier to use the application and enabled [me] to stick to my data and my character to some extent" (P23, TR+AS) and "Having characters definitely help make it seem fun and facing off against random people also [made] it exciting" (P1, SR+AS). The advantages of these features - lowering the barrier to using the application and ensuing anonymity - are connected to the main advantage of gamification, engagement in physical activity (Froehlich, 2009).

The negative comments were mostly about the static features of gamification and a lack of desired control. Some of the participants expected more interactivity and control over the heroic gamification characters and leaderboards in the application. Exemplar comments included: "More of a data tracking device than a game" (P14, SR+MS), "I did not find it was like playing a game" (P9, SR+MS) and "It is not like the real game because of no way to control my character, but the concept is interesting" (P17, TR+AS).

However, for some of the participants, especially at the maintenance stage, the gamification features did not seem to be effectively and positively persuasive as they were more or less neutral. Their comments were "The game feature did not make me run

more or less, but it did give something different to look at besides just numbers" (P24, TR+MS), "I do not feel particularly motivated by games. Although the game aspect may be helpful for some people, it did not increase or decrease my level of interest in the app or in running" (P13, SR+MS) and "I run for myself, not because of any game or competitive features" (P28, TR+MS).

(3) Satisfaction with Social Competition

The concept of social competition (or social cooperation) was rated as moderately positive, but the satisfaction scores decreased from the first month to the second month. The concept of social competition received different feedback depending upon the participants' stage of behavior change and their preferences about competition.

On the one hand, the positive feedback included "The sense of competing with others is useful" (P17, TR+AS), "It helped me in being motivated to run more often" (P5, SR+AS) and "Competition with my teammates and others is another motivation to me. Seeing the comparison table is also good motivation" (P16, TR+AS). On the other hand, negative feedback included "I'm not interested in competing with others" (P10, SR+MS), "I didn't really compare my running activity with others because everybody's physical status is different" (P5, SR+AS), "Little extra motivation, especially since I run alone most of the time" (P24, TR+MS) and "I am not much comfortable competing with others or being defeated by someone I don't know" (P23, TR+AS). Other participants, who were at the action stage, rated the social competition feature as neutral, "I am not very competitive, so I am neutral about this feature" (P3, SR+AS) and "I did not reach at the level of competing with others, maybe sometime later" (P22, TR+AS). This social

competition (or social cooperation) seemed to be favored differently according to the runners' stages of behavior change and their personalities.

5.3.2. External Factors which Make Participants Run

The participants were also asked about how they motivated themselves (or how they wanted to be motivated) when they did not want to do physical activities and when their motivation decreased. They were also asked what external factors they needed to increase their motivation. Note that the categories below were subjectively selected and not mutually exclusive. Overlaps may exist.

Table 16. A summary of external factors, which made and will make run

Categories of external motivational factors	Comment counts
Health-related	14
External reinforcement (or regulation)	12
Environmental factors	12
Running buddy	11
Rewards	8
Recognition of others' activities	6
Other factors	2

5.3.2.1. Health-related

Although rather banal, the most frequent answer was "health-related" motivation, as mentioned by 14 participants. These participants' comments showed that a need to be healthy and look good was strongly effective in regard to increasing motivation when the

participants did not want to take part in physical activities. Exemplar answers were “I was motivated to run when I realized I was starting to lose weight” (P16, TR+AS), “Just knowing that I need the exercise or want the time alone are great motivators even when I do not want to run” (P24, TR+MS) and “Weight and body shape. Friends who have nice body shapes” (P6, SR+AS). One participant commented as an additional feature in the future application “It would be helpful and quite motivational if somebody tells (warns) me whether my BMI score or any healthy score is in the danger zone or in the safe (healthy) zone” (P13, SR+MS).

5.3.2.2. External Reinforcement (Regulation)

The second most frequent answer (12 counts) was related to the category of ‘external reinforcement (regulation),’ which included self-regulation and external regulation. Comments related to self-regulation included “My own restlessness when I don't run” (P10, SR+MS), “Some reinforcement or feeling of guilt when I don't run” (P25, TR+MS) and “Push myself that I need to exercise for weight control” (P3, SR+AS). Comments about external reinforcement were divided into two subcategories: ‘external reinforcement by people’ or ‘external reinforcement by objects’ depending on the motivational agent needed to regulate the participants. The comments related to the external regulation by people included “Others’ advice” (P18, TR+AS), “Guidance by actual person or friends” (P6, SR+AS) and “Someone who pushes me to run or who runs with me” (P13, SR+MS), while the comments related to external regulation by objects were “Reminders” (P17, TR+AS), “Tight schedule for running practice” (P30, TR+MS), “Any enforcement, preparation plan for upcoming marathon” (P29, TR+MS) and

"Reminders of intense workout schedule" (P8, SR+MS). One opposite remark was "Telling someone I was going to run made me feel obligated" (P7, SR+AS).

5.3.2.3. Environmental Factors

Interestingly, weather conditions were the second most frequent category of external motivational factors (12 counts), the same count as the external reinforcement (regulation) factor. The participants commented that they would go out for activities if the weather got nice: "Taking advantage of good weather" (P7, SR+AS) and "Pleasant weather" (P19, TR+AS). Although nice weather could be one of the reasons for activities, bad weather did not seem to be a direct reason for performing other activities that replace running. The participants mentioned that they would replace the type of activity without mentioning their primary reasons: "I go to a gym when the weather gets bad" (P9, SR+MS), "Did a different type of workout instead" (P28, TR+MS) and "I cannot do anything with the weather. I usually go to the gym to run or do other activities, such as workout, indoor tennis" (P15, SR+MS).

5.3.2.4. Running Buddy

Having a running buddy was considered the third most effective motivational factor by the participants (11 comments). Although it turned out that the runners at the maintenance stage usually ran alone and a feature of belonging to a team was not considered to be one of the main factors that were strongly effective in regard to increasing a participant's running activity. The participants who were runners at either the action or maintenance stages commented that having a running buddy was and would

be an effective motivational factor or trigger for an activity: “Someone who can run with me or something which is a trigger to move” (P27, TR+MS), “Presence of a friend or companion to run with” (P2, SR+AS), “If I made a promise with a friend, I would more likely to go running, even I am busy or tired” (P5, SR+AS), “If my friends asked me to run together” (P30, TR+MS) and “Running with close friends and running buddy” (P22, TR+AS).

5.3.2.5. Rewards

‘Rewards’ as a motivational factor was stated eight times. The forms of the rewards varied: “Any real or virtual benefits” (P27, TR+MS), “Give myself rewards after running (eat some delicious food or buy something)” (P11, SR+MS), “Showing some possible benefits? Virtual rewards? Visually or Verbally?” (P20, TR+AS), “I motivate myself with edible treats or I watch movies, while I am on the treadmill” (P28, TR+MS). However, no weighted preference existed for the form of the reward.

5.3.2.6. Recognition of Others’ Activities

Seven participants answered that recognizing activities from others would be a motivational factor: “Updates from others going to gym” (P1, SR+AS), “I was motivated when I spent time evaluating the runs of my friends” (P25, TR+MS) and “Getting to know others running or working out” (P8, SR+MS). As additional features in the next version of the application, two of the participants mentioned effective motivational factors when they were notified about others’ running activities completed in the application: “Seeing status notifications of team members completing a run” (P29,

TR+MS) and “Motivation drawn from seeing other's progress in the running charts” (P19, TR+AS).

5.3.2.7. Other Motivational Factors

There were two other interesting answers about motivational factors. One participant mentioned: “Get inspiration from role models and quotes” (P7, SR+AS). Another participant mentioned going for a run when he or she wanted to be alone: “Just knowing that I want the time alone is a great motivator even when I do not want to run” (P24, TR+MS).

5.4. Findings from the Additional Interview

Due to the decreased frequency of the number of running activities by some of the participants in the second month, an additional survey was conducted two weeks after the end of the study to ask about the main reasons why their frequency of use decreased and whether their main reasons were related to the elements of the HamkeRun application. Four of the participants completed the questionnaire. All of the participants who completed the additional survey were runners at the action stage; three males and one female.

5.4.1. Main Reasons for Low Frequency of Running

Table 17. Main reasons of low frequency of running by participants.

Main reasons for low frequency of running activities	Counts
My motivation to run has been decreased	3
I have been busy when I wanted to run (Running was not my first priority)	3
Weather has been too severe to run	2
I felt guilty that I had not used the application initially, which made it harder to get started using it	2
The HamkeRun application was not what I expected to help me run more	2
I have other physical activities replacing running (such as workouts, yoga, or swimming)	1

One participant specifically stated that his studies and exams caused him to be irregular in doing exercise and running. Three of the four participants answered that they didn't do physical activities in severe weather, while one participant did go to the gym, did workouts, steppers and crossfits during the severe winter.

5.4.2. Additional Motivational Factors

The survey included question sets about how the participants wanted to get motivated regardless of the existence of this mobile application. Two of the participants answered that they wanted to have a "More personalized and constant reminding system" (P17, TR+AS), "Telling me [the] benefits of running and setting up a knowledge base, providing tips for running" (P7, SR+AS). This suggests that the runners wish to receive constant and deliberately customized notifications according to their stages of behavior

change. In addition to this, it would be nice to provide the runners, especially at the beginner level (at the action stage), with running tips and the benefits of running so that they can learn to run effectively and understand why they need to run.

5.5. Lessons Learned and Design Principles for Persuasive Application Developers and Designers in the Health-related Domain

5.5.1. Lessons Learned from the Study Results

Users at different stages of behavior change want different services

Services (or functions in the mobile application) should be provided to the users differently and more deliberately depending upon their stages of behavior change because each individual is at a different stage and has different views on exercise activities. One participant specifically mentioned that the step-by-step achievement list and leaderboard ranking in the HamkeRun application showed too wide of a spectrum of achievements or users from beginners to experts, which discouraged him from competing. For the same reason, the participant pointed out that some of the functions were irrelevant to his or her needs. Customizable functions or services by users would be a helpful way to resolve this issue.

'Social grouping' is not always good

A social grouping function or related services in the application should be provided appropriately depending upon the users' stages of behavior change and initial

intents for usage. This is based on the result that it failed to show the expected social effect that the number of running activities by the team runners would be significantly higher than the number of activities by the single runners and that the satisfaction of the team runners would be significantly higher than the satisfaction of the single runners. This was mainly because the experienced runners (at the maintenance stage) preferred running alone and were not motivated by belonging to a team. However, many of the participants, regardless of their stages of behavior change, considered the 'social function' to be one of the most favorite motivational factors when their motivation decreased. This suggested that the social function would work fine for runners who wanted to run with their friends and running buddies for fun, health-related and recreational purposes.

Be cautious about users' high expectations for gamification

Despite the benefits of gamification as demonstrated in the previous chapter, the users may expect (a lot) more than what would be in the application when employing the concept of gamification. At the beginning of the HamkeRun study, all of the participants were informed that game-like features were employed in the application, such as in the leaderboard and heroic characters. However, some of the participants expected more than the existing gamification features and wanted to have more interactivity and control over the characters and graphical charts. The lack of this ability affected their satisfaction scores, rather moderately negatively. Therefore, one should be careful when employing the concept of gamification so as to not to give higher expectations and decreased satisfaction. Furthermore, each individual has different senses of playfulness and fun toward games despite whether the games are well-made or considered playful or fun. It

would be important not to focus too much on gamification, but to balance gamification and the main purposes of the application, such as providing educational or health-related information. Finally, the gamification features should be fun, at a minimum.

Motivation is still a different domain from a domain of actual behavior

Although some of the participants considered themselves to be highly motivated internally or externally, the numbers of their running activities did not significantly increase. In other words, highly motivated participants still needed additional triggers, which would be more powerful, repetitive and sustainable, to cause them to complete additional running activities. For this reason, it would need more considerations in regard to the ways in which to transfer from motivation to physical activities.

Several of the participants mentioned the need for more constant and personalized notifications about running tips and reminders of their running schedules. One runner at the action stage whose number of running activities had decreased commented not only about his or her decrease in motivation but also the need for more personalized notifications, including running tips telling him or her the benefits of running regularly: "Telling me benefits of running and setting up a knowledge base, providing tips for running" (P7, SR+AS). Another action stage runner mentioned: "More personalized and constant reminding system" (P17, TR+AS). This indicates that the motivation of the runners at the action stage seemed to be fragile to maintain, thus requiring repeated internal and external efforts. Therefore, persuasive system developers and designers should consider both the more personalized spark trigger showing the benefits of running and the signal trigger type reminding the runners of their schedules more often without

causing annoyance. It might be a good idea to utilize the spark trigger for runners at the action stage and then increase the use of the signal trigger as the runners' stages of behavior change progress.

Moreover, it would be a good idea if developers and designers were to utilize the concepts of gamification and information visualization in the trigger. The concept of gamification induced significant increases in the total number of activities and indirectly lowered the barriers to using the application. Two of the participants mentioned, "For me, other apps in the app store pushed people to run more and more to some extent, but this app did not push much. This game feature seemed to work like that indirectly" (P5, SR+AS) and the "Game character lowered the barrier to use the application and enabled me to stick to my data (my character) to some extent" (P23, TR+AS). The concept of information visualization may serve as an effective spark trigger if visualized representations of information about the participants' activities make more persuasive, attractive and engaging.

Other technical tips

This subsection provides a small set of technical guidelines that were obtained from the development phase through the end of the study. The first tip is to balance workload between the mobile application side and the server side. When the first complete version of the HamkeRun application was initially released to the first group of participants, the user performance data, such as the average speed and user ranking, were calculated on the mobile phone (users' side). However, when the participants produced a lot more activity data than initially expected, the number of the calculations explosively

increased, which negatively influenced the performance and execution time of the application, and caused some of the participants to leave after the first month of the study. Therefore, the expensive parts of various calculations might be off-loaded to the server side in order to reduce their impact on the mobile application. Several BaaS (Backend As A Service) architectures, such as Kinvey (http://www.kinvey.com), and Parse (http://www.parse.com), provide features supporting for stable, faster and easy server side operations as well as horizontal scalability, user management, and security. If this kind of BaaS architecture is not an available choice, using a NoSQL database for the mobile application's data store, such as MongoDB (http://www.mongodb.com) or CouchDB (http://www.couchdb.com) might be a better alternative than a traditional SQL database by offering horizontal scalability, simplicity of design, low latency and high performance.

The second tip is that the application should be stable, fast and error proof. When errors were found and the application became slow as the calculation time increased, the satisfaction of the participants decreased. This negatively influenced the continuity of the study as well as the participants' satisfaction with the application.

In the same vein, the third tip is that the designers and developers should not place much focus on the beauty of the app. This is based on my experience implementing the HamkeRun application as the result of foci on aesthetic negatively resulted in decreased performance, slow execution speed and slow tap response time.

5.5.2. Design Principles

The following are a small set of design principles for mobile application developers and designers for behavior changes in health-related domains. These principles were derived from the results of the HamkeRun study and extracted from the persuasive strategies and principles in section 2.3, which are contextually most relevant. The design principles are summarized in Table 18.

(Personal) Monitoring

The first principle, (personal) monitoring, should be used to provide users with a way to keep track of their activities and evaluate their progress toward their desired goals. The users should be able to track their progress on the path to achieving their desired goals and adjust as needed. This principle is similar to the 'self-monitoring' principle (Fogg, 2003). Examples of this principle include monitoring running activities in RunKeeper and Nike+ Running as well as sensing users' transportation activities in UbiGreen (Froehlich et al., 2009).

Personalization

The second principle, personalization, should be used is to provide tailored information according to users' interests, needs, personality, concerns and usage context so that they can engage more in their target behavior, day-to-day behaviors and attitudes. Studies on persuasion have revealed that personally relevant content in persuasive messages yielded significantly increased involvement, extensive cognitive elaboration and stronger emotional reactions (Pertty & Cacioppo, 1979; Pretty, Cacioppo, &

Schumann, 1983; Darley & Lim, 1992, as cited in Bakkes; Tan & Pisan, 2012). In addition, personally tailored information has been positively related to the increased effectiveness of persuasion (Hirsh, Kang, & Bodenhausen, 2012). Online shopping websites use customers' information, such as history of purchases and visits, to persuade them to buy more items. This personalization principle is similar to the 'Tailoring' (Fogg, 2003) and 'Personalizing' principles (King & Tester, 1999; Torning & Oinas-Kukkonen, 2009). Possible examples of this principle are individuals' personalized profiles on Facebook and Medicare portals as well as customized characters in the HabitRPG application (https://habitrpg.com/) and MMO (Massive Multiplayer Online) games.

Playfulness and Flow

The third principle, playfulness, should be used to provide playful experiences for users to engage in while performing a target behavior. Engagement in an activity can start with playful experience (Polaine, 2005). Thus, a well-designed component of playfulness is the first step toward persuasion. It is worth combining the components of interactivity and a sense of control in the game elements to prevent disappointment at gamification. However, a balance should exist between playfulness (enjoyment) and the primary purpose of the application. The idea of Flow (Csikszentmihalyi, 1990) can also be brought to bear here to increase engagement, which would imply value in including the eight major components of flow in a persuasive application (Csikzentmihalyi, 1990, as cited in Chen, 2007): a challenging activity requiring skill, a merging of action and awareness, clear goals, direct and immediate feedback, concentration on the task at hand, a sense of control, a loss of self-consciousness, and an altered sense of time.

Social support

The fourth principle, social support, includes three sub-principles: social grouping, social surveillance and social comparison/competition. Social grouping is the means by which one provides users with ways to connect socially with others so that they can positively motivate each other to perform target behaviors and achieve desired goals. This principle is similar to the 'Social proof' principle (Cialdini, 2001), 'Social validation' principle (Arroyo, Bonanni, & Selker, 2005) and 'Social support' (Oinas-Kukkonen & Harjumaa, 2009). Activator (Romero, Sturm, Bekker, Valk, & Kruitwagen, 2010), which was designed to encourage elderly residents to participate more in physical and social activities, is an example of the application of this social grouping principle.

Social surveillance is a means of providing users with opportunities to observe others' activities and share their own activities in order to increase the likelihood of performing a target behavior and achieving a desired goal. An example of the application of social surveillance is Bouncer (Nelson, Megens, & Peeters, 2012), which visualizes physical activities of team members. This principle is the social version of the 'surveillance' principle (Fogg, 2003).

Social comparison/competition provides users with a mechanism by which to compare/compete with social peers. The ranking table in WattsUp (Foster, Lawson, Blythe, & Cairns, 2010) is an example of this social competition principle in practice. However, there should be considerations about who will be grouped within a social group. My findings here demonstrate that merely grouping individuals with unknown others will not guarantee the intended effectiveness of social support.

(Virtual) Rewards

The fifth principle, (virtual) rewards, should be used to provide users rewards for the completion of their activities so that they can perform target behaviors more frequently and effectively. This is based on the fact that positive stimulus and consequences lead to positive behavior performed and repeated and is similar to the 'Reciprocity' (Cialdini, 2001) and 'Positive reinforcement' principles (Arroyo, Bonanni, & Selker, 2005). Virtual rewards can be found in HealthSeeker (Kamal, Felas, Blackstock, & Ho, 2011) and many online games and shopping sites.

Reminders with suggestions

The last principle, reminders with suggestions, is the notion of providing users with suggestive prompts to perform the target behavior at an opportune moment and in the right context according to their stages of behavior change. For novice users, reminders communicating the benefits of performing a target behavior may be more effective, while simpler and less annoying reminders will be more effective for experienced users. Playful Bottle (Chiu et al., 2009) utilizes automated reminders to motivate people to drink healthy quantities of water regularly. This reminder principle is related to the 'Conditioning,' 'Just-in-time prompts' (Fogg, 2003) and 'Positive reinforcement' principles (Arroyo, Bonanni, & Selker, 2005). Recommended items in online shopping sites and a suggestion feature for alternative food items in iCart (Kallehave, Skov, & Tiainen, 2010) are examples of the suggestion principle in practice. The suggestion principle is similar to Fogg's articulation of the 'Suggestion' principle (Fogg, 2003).

Table 18. Design principles for persuasive application developers and designers in health-related domains

Principles & Strategies	Implementation	Examples
(Personal) Monitoring	Provide users to keep track of their activities and evaluate progresses towards their desired goals.	RunKeeper, Nike+ Running, and UbiGreen (Froehlich et al., 2009)
Personalization	Provide information that is personally tailored to users' interests, needs, personality and context so that they can engage more in their target behavior	Personal profiles on Facebook, and customized game characters in MMO (Massive Multiplayer Online) games
	Provide customizable services to users according to their different stages of behavior change	
Playfulness	Provide playful experience to engage in performing a target behavior.	Active Video Games (AVGs), such as DDR, Nintendo Wii Fit games
	Provide game elements without giving too high expectations	
	Balance between game features and initial purpose of the application preventing from disappointment	
Social Support	Provide users ways to connect social others so that they can positively motivate each other to achieve their desired goals	Activator (Romero, Sturm, Bekker, Valk, & Kruitwagen, 2010)

	Provide users to observe others' activities (and share) to increase the likelihood of performing a target behavior	Bouncer (Nelson, Megens, & Peeters, 2012)
	Provide users to compare / compete with social peers	Ranking system in WattsUp (Foster, Lawson, Blythe & Cairns, 2010)
(Virtual) Rewards	Provide users (virtual) rewards for completion of their activities so that they can perform the target behavior more frequently and effectively	HealthSeeker (Kamal, Felas, Blackstock & Ho, 2011), online games, and shopping sites.
Reminder with Suggestion	Provide users to remind to perform the target behavior at appropriate moment and the right context according to their stages of behavior change	Playful Bottle (Chiu et al., 2009) and iCart (Kallehave, Skov, & Tiainen, 2010)
	Provide reminders telling the benefits of performing a target behavior for beginner users	
	Provide simpler and less annoying reminders for experienced users	

CHAPTER 6: CONCLUSION

This chapter presents the contributions of the study, limitations of the study and future work.

6.1. Contribution of the Study

This dissertation resonates with efforts to confront the global and societal problem of physical inactivity, which is the leading cause of disease, death and disability. The main focus of this dissertation, sustainable behavior change through persuasive technology in a running context, contributed to some extent in overcoming the limitations, including low dietary effectiveness, of the existing tools as well as a lack of sustainable effects in the long-term and proof of effectiveness shown only in laboratory settings.

Specifically, this study contributes to advancements in the field of human-computer interaction in four aspects. The first contribution is to provide the theoretical framework in the context of running that combines two separate theoretical models: the transtheoretical model of behavior change (TTM) and Fogg's Behavior Model (FBM). These two theoretical models were iteratively refined based on the results of the quantitative and qualitative analyses. The TTM was used to explain the cognitive and motivational models of runners in each stage of behavior change when they received the persuasive motivational elements from the HamkeRun application. In addition, the FBM was used to interpret the existence of the gap between motivational and behavior levels. These theoretical frameworks will serve as the basis for further research to identify ways

by which to narrow that gap more effectively and quickly, so that highly motivated runners are able to sustain motivation and perform running activities more regularly.

The second contribution of this dissertation is not only to design and implement a mobile application employing a set of persuasive technologies and the concepts of information visualization, gamification and social grouping, but also to test empirically the effectiveness of these concepts within the context of running. When the concepts were empirically tested, the foci were placed not only on the effectiveness of these concepts on internal motivation, external motivation, satisfaction and number of running activities, but also on effectiveness by different subgroups, deliberately grouped by runner type (single and team runners), stage of behavior change (action and maintenance stages), existence of gamification and gender. I believe that identifying the underlying mechanisms for how the persuasive techniques and concepts of the motivational elements employed in the HamkeRun study affected the cognitive processes in the users will provide helpful knowledge for other researchers and developers studying persuasive technology.

The third contribution is the tangible mobile application developed, which combines the concepts of information visualization, gamification and social grouping. Although it still needs improvement, it is believed that the HamkeRun application served as a successful test bed by which to test the participants' cognitive and behavioral results, including inducing changes in internal motivation, external motivation, satisfaction and number of running activities. The HamkeRun application can be refined to test any further combination of motivational elements, not just in health-related domains, but also in other applicable domains.

The fourth contribution is that this research provides design guidelines for persuasive application developers and designers in health-related fields. These guidelines were based on the findings of this dissertation. The guidelines will help developers and designers who want to build effective and persuasive applications, while preventing them from improper user targeting and simply building a collection of seemingly fancy and trending concepts, such as the mere joining concepts of 'social' and 'green technology,' without deeper and contextual considerations of those concepts. While the guidelines are limited contextually to health-related fields, it is believed that these recommendations can serve as a basis for other fields and researchers to build upon.

6.2. Limitations of the Study

First, the total sample size was smaller than hoped, which may have impaired the analyses (e.g., violation of some of the assumptions of the parametric tests). Due to this reason, non-parametric tests were employed in order to analyze the effects of the independent variables. Therefore, standard parametric analyses of the interaction effects among the variables were not possible. Furthermore, the participants were not equally assigned to the subgroups, which lessened the power of the analysis. For instance, under the gamification treatment, the number of runners with gamification was 18, while the number of runners without gamification was 12 at the end of the study, although the enough number of participants was initially planned to recruit and balance. In addition, more than half of the participants (32 out of 52) were university students, so the total numbers of their running activities were influenced by class schedules, homework and

exams, which made it difficult to analyze or disjoin the main factors of the changes in the dependent variables from the external factors occurring at the same time as the study.

Second, the study was conducted over two months. As described in Chapter 2, no empirical evidence exists about the factors making the participants participate in physical action regularly. Therefore, the study may have produced different results if its duration were different.

The next limitation is the data collection was conducted under the oddly severe weather of Indiana, which was recorded as among the top 10 coldest winters in the Midwest on record. On this account, some of the participants left the study, the study had to stop for three months until weather become more normal and the data collection required a small group of new participants. Although all of the participants were in the same condition, meaning that they suffered from the same severe weather, possibly different results could have been obtained if the study were conducted in different weather conditions, without stoppage, in different places or in different seasons.

Fourth, there were technical issues in the HamkeRun application, which was not optimized initially at the beginning of the first month. This meant that the app was slow and had some errors, but these issues were resolved by the end of the first month. These problems might have negatively influenced the perceptions of the usability of the application and the satisfaction of the users, which, in turn, possibly affected their frequency of use of the HamkeRun application. Moreover, because the HamkeRun application required a mobile phone running Android OS 4.0 or higher, the speed and performance of the application were slower for some of the participants who installed the HamkeRun application on older phones (even with Android OS 4.0 installed).

Finally, some external factors may have existed, especially in regard to internal motivation scores. The results of the non-parametric tests showed that the internal motivation scores of most of the runners in the subgroups steadily increased over two months. A possible rationale could be that the runners had been accustomed to the severe weather and taken up other physical activities, such as workouts or other indoor sports, under these conditions that were not reported in the survey, therefore, their self-efficacy was increased due to an external source. It might be hard to believe that the HamkeRun application solely and directly influenced the increases in internal motivation scores, but it is hard to identify all of the possible external factors in the current experimental design.

6.3. Future Work

The HamkeRun study provided some insights into persuasive interface design techniques that could be combined with the concepts of information visualization, gamification and social grouping in the context of running. Although the results of the empirical tests showed the potential of these techniques and motivational elements, it failed to provide empirical evidence of the effectiveness of these techniques on the satisfaction and number of running activities in spite of the increases on internal and external motivation. Therefore, future research needs not only to explore ways to increase these constructs, but also investigates the mechanisms necessary to transition from motivation to the actual activity in regard to the perspectives of human cognition and application development.

The next direction would be to re-conduct the experiment in different places and in different seasons with different sets of participants in large enough numbers so that the

treatments (i.e., runner type, stage of behavior change, gamification and gender) are balanced. This is based on the special situation in Indiana suffering severe weather last year and the fact that more than half of the participants were university students influenced by their semester schedules. Thus, new experiments should investigate the effectiveness of these persuasive techniques and motivational elements in more generalizable conditions. The results of these tests will be expected to produce more reliable data and stronger effect sizes.

Third, the concept of social grouping needs to be investigated in an elaborate experimental design. As shown in the comments by the participants, the concept of social grouping was favored for the purposes of fun, health and recreation, while the runners in the maintenance stage did not consider it as necessary for their running. This was quite different from my expectations. Therefore, the effects of the social grouping concept should be tested with more subgroups, such as a team of participants who are unknown each other and a team of participants who are known to each other.

Fourth, it would be worth investigating the ways in which to connect motivation to the actual activities performed. This study could not show the significant increases in the number of running activities of the participants even though some of the participants were considered to be highly motivated internally or externally. This means that people still need effective triggers to perform their actions immediately or sustainably, regardless of any internal or external factors, such as weather or laziness. Therefore, the design and evaluation of the effective triggers in the application need to also be tested.

Next, the various interventions of the persuasive motivational elements on different groups need to be tested. The results of the exploratory analyses showed that the

female, single runners showed significant increases in the number of running activity changes in spite of the small sample size (N=4), which indicates that some of the motivational elements in the HamkeRun application might work better and be more beneficial for certain groups of people (in terms of starting to perform actual behavior). Therefore, it would be worth investigating more interventions tailored to certain groups of people to maximize efficacy.

Sixth, it would be interesting to explore the effects of persuasive motivational elements from a perspective of motivational affordances. For some of the participants, especially at the maintenance stage, the gamification features were not as effective and positively persuasive as my initial expectations, but more or less neutral. It seems that the neutral response to the gamification elements may not have been due to the users' stage of behavior change, but more related to their personalities. This hypothesis is based on the assumption that people with different personality types will be differently motivated by and respond to different motivational affordances, which are embedded in a persuasive motivational application. Karanam et al. (2014) also showed a correlation between different personality traits and different categories of tracked behaviors when the participants were asked to use the HabitRPG application (https://habitrpg.com/). Therefore, possible follow-on tests may include an investigation about a potential correlation between persuasive motivational elements in the persuasive running application and the Big Five personality types.

Other interesting topics that should be tested include the effects and privacy concerns of a social grouping feature used to find and connect to either known or unknown participants located nearby, the effect of having more control over gamification

and the graphical charts on motivation, satisfaction and the total number of running activities, and the effect of employing different types of motivational elements and persuasive techniques in the mobile application.

APPENDICES

Appendix A. Demographic Questionnaire Items

Basic demographic questions

1. What is your age group?

   18~20 21-25 26-30 31-35 36-40 41-45 46-50 51-60 60+

2. What is your gender?

   Female Male

3. What is your current height?

4. What is your current weight?

5. Racial Group

   Asian Black Hawaiian Native American White Hispanic or Latino Other

Running experiences questions

6. Each time you go running, on average how long do you usually run for?

   < 0.5 hour 0.5 ~ 1 hour 1 ~ 2 hour 2 ~ 3 hour 3 hour +

7. How many times do you usually run in a week?

   0 1 2 3 4 5 6 7

8. How many years have you been doing the running activity you indicated in question 6 and 7?

   < 1 1-2 2-3 3-4 4-5 5+

9. Right now, are you running more, less, or the about same amount as three months ago?

Much less	A little less	About the same	A little more	Much more

10. What are your main reasons to do running activity? (Choose all that apply)

Stress relief	Lose weight or stay in shape	Train for events such as marathons, triathlons, or other races	Social interaction	Other

11. If you chose 'other', please describe in detail.

12. Do you run alone or with your friends / family?

Alone	With Friends/Family

13. If you chose 'Friends/Family', what are the main benefits of running with friends / family?

Technological Aid Use Questions

14. Have you ever used a technological aid, such as mobile app or GPS device, during your run?

Yes	No

15. If yes, please write name of the app / device and describe the main reasons why you use it

16. How frequently do you use the technological aid during your activity?

Not at all	Rarely frequently	Average	Very frequently	Always

Appendix B. Questionnaire Items for Single / Team runners

The following are on a scale of "Strongly Disagree" to "Strongly Agree"
(0: "Strongly Disagree", 1: "Disagree", 2: Disagree Somewhat, 3: "Agree Somewhat", 4: "Agree" and 5: "Strongly Agree")

[IM] 1. I am confident I can participate in regular running activity when I am tired

0 1 2 3 4 5

[IM] 2. I am confident I can participate in regular running activity when I am in a bad mood

0 1 2 3 4 5

[IM] 3. I am confident I can participate in regular running activity when I feel I don't have the time

0 1 2 3 4 5

[IM] 4. I am confident I can participate in regular running activity when I am on vacation

0 1 2 3 4 5

[IM] 5. I am confident I can participate in regular running activity when it is raining or snowing

0 1 2 3 4 5

[EM] 6. Seeing my activity data motivated me to run more regularly

0 1 2 3 4 5

[EM] 7. Seeing my progress motivated me to run more regularly

0 1 2 3 4 5

[EM] 8. Seeing others' running activity data motivated me to run more regularly

0 1 2 3 4 5

[EM] 9. Seeing running activity data in a graphical chart motivated me to run more regularly

0 1 2 3 4 5

[EM] 10. The feature of competing with others provided in the mobile application motivated me to run more regularly

0 1 2 3 4 5

[EM] 11. The gamification features (zombies and virtual badges) provided in the mobile application motivated me to run more regularly

0 1 2 3 4 5

How satisfied are you with the following features of the application?

12. The way data was shown in graphical charts

Completely unsatisfied	Unsatisfied	Somewhat unsatisfied	Somewhat satisfied	Satisfied	Completely satisfied

13. a. Why or Why not?

14. The way the application was like playing a game

Completely unsatisfied	Unsatisfied	Somewhat unsatisfied	Somewhat satisfied	Satisfied	Completely satisfied

14.a. Why or Why not?

15. The way I could compete with others during my run

Completely unsatisfied	Unsatisfied	Somewhat unsatisfied	Somewhat satisfied	Satisfied	Completely satisfied

15.a. Why or Why not?

Open-ended Questions

16. When you didn't (or couldn't) run, what were the main reasons? (Check all that apply)

    Weather
    Busy
    Health Condition
    Need additional trigger
    Other? (Please specify)

17. When you didn't (or couldn't) run, what external factors were / are effective to make you go running?

18. When you don't want to run, what external factors do you need to go running?

19. Check all that motivated you
    a. Visualization of my data
    b. Visualization of others data
    c. Game-like features
    d. Social features
    e. Other? (Please specify)

20. Any additional features you think it would be better to have??

Appendix C. A Follow-up Questionnaire Questions Asking Main Reasons for Low Frequency of Running Activity

1. Please select the reasons why you didn't use the application. Check all that apply and indicate what percentage this reason accounted for why you didn't.
   a. Weather has been too severe to run.
   b. I have been busy when I wanted to run (Running was not my first priority)
   c. My motivation to run has decreased
   d. I have other physical activities replacing running (such as workouts, yoga, or swimming)
   e. I use other mobile applications for running (e.g., MapMyRun, RunKeeper)
   f. I use other devices when I run (e.g., GPS watcher, pace checker)
   g. I felt guilty that I had not used the application initially, which made it harder to get started using it.
   h. The HamkeRun application is not what I expected to help me run more
   i. Other reasons:

2. When the weather has been severe, have you done physical activities? If so, what did you do? (If not, write 'No')

3. If your motivation to run were decreased, how would you increase your motivation? (If not, write 'No')

4. If your motivation to run were decreased, what features from a mobile application would increase your motivation? (Please answer specifically)

5. If you used other mobile applications (e.g., MapMyRun, RunKeeper), what were the most effective elements (features) in the application which helped you run more? (If not, write 'No')

6. If you used other devices (e.g., GPS watcher, pace checker), what were the most effective elements (features) which helped you run more? (If not, write 'No')

7. "Using any mobile application for running (such as MapMyRun) does not help me to run more." If this statement is right, what makes you run? (If not, write 'No')

8. "Using any current mobile application for running, such as MapMyRun, does not work for me to run more. I would use it only if the feature were provided." If this statement is right, what feature do you want to use to make you run? (If not, write 'No')

9. "I know I have several mobile applications to track my running activities installed in my phone. But, I barely use any of these applications". If this statement is right, what are the main reasons why you don't use? What are required for you to use the application? (If not, write 'No')

10. "The HamkeRun application is directly related to the reason why I didn't / couldn't run." If this statement is right, what are the main elements (features) not working well? (If not, write 'No').

11. [The HamkeRun application] How much were graphical charts (or visualization) showing your data useful to help you run?

12. [The HamkeRun application] How much was your data (whether it's visualized or not) useful to help you run?

13. [The HamkeRun application] How much was the 'game-like features (such as game characters, scoreboard table)' useful to help you run?

14. [The HamkeRun application] How much were the social support/competition features (such as team setting) useful to help you run?

15. [The HamkeRun application] How much was the feature of 'push notification (or notification alert)' helpful to make you run?

16. Are there any additional features you would want to use in the next version of the HamkeRun application?

Appendix D. A Summary of Demographic Information of Participants

Table 19. A summary of demographic information of participants

Category	Classification	Total Number (N)
Gender	• Male	29
	• Female	23
Age group	• 18 ~ 20	8
	• 21 ~ 25	24
	• 26 ~ 30	6
	• 31 ~ 35	7
	• 36 ~ 40	6
	• 41 ~ 45	1
Stage of behavior change	• Action stage	26
	• Maintenance stage	26
Race group	• Asian	19
	• Black	3
	• Hispanic	2
	• White	28
Duration of running	• Less than 0.5 hour	13
	• 0.5 ~ 1 hour	28
	• 1 ~ 2 hour	11
Run in a week	• Not recently	2
	• 1 time	14
	• 2 times	17
	• 3 times	12
	• 4 times	5
	• 5+	2
Running experiences in years	• Less than a year	15
	• 1 ~ 2 years	11
	• 2 ~ 3 years	7
	• 3 ~ 4 years	2
	• 5+ years	7

Appendix E. A Summary of Wilcoxon's Signed Rank Tests Result of the Number of Running Activities

Table 20. A summary of Wilcoxon's signed rank tests result of the number of running activities.

Between subject factor	Split by	*Z*	Sig. Value
Runner Type	Single Runner	-0.54	.539
Runner Type	Team Runner	0.39	.700
Stage of Behavior Change	Action Stage	-1.55	.122
Stage of Behavior Change	Maintenance Stage	0.95	.344
Gamification	With Gamification	0.60	.549
Gamification	Without Gamification	-1.21	.227
Gender	Male	0.81	.420
Gender	Female	-1.33	.183

Appendix F. A Summary of 2 Split Mann-Whitney Tests Result of the Total Number of Running Activity

Table 21. A summary of 2 split Mann-Whitney tests result of the total number of running activity

	Effect of	(split) Effect on	U	W	z	Sig.
Runner type x Stage of behavior change	Runner Type	Action stage	16.5	52.	-1.34	.189
	Runner Type	Maintenance stage	35.0	63.	0.81	.463
Runner type x Gamification	Runner Type	Gamification	32.5	77.	-0.71	.489
	Runner Type	No Gamification	18.0	39.	.000	1.00
Runner type x Gender	Runner Type	Male	31.5	67.	-1.03	.310
	Runner Type	Female	18.0	46.	0.76	.527
Stage of Behavior Change x Runner Type	Behavior Stage	Single Runner	41.5	77.	1.57	.121
	Behavior Stage	Team Runner	55.0	83.	3.13	.001
Stage of Behavior Change x Gamification	Behavior Stage	Gamification	71.0	126	2.76	.004
	Behavior Stage	No Gamification	33.0	48.	2.56	.010
Stage of Behavior Change x Gender	Behavior Stage	Male	79.5	115	2.94	.002
	Behavior Stage	Female	23.0	51.	1.70	.109
Gamification x Runner Type	Gamification	Single Runner	4.5	25.	-2.66	.005
	Gamification	Team Runner	20.0	41.	-0.83	.456
Gamification x Stage of behavior change	Gamification	Action stage	7.5	35.	-2.39	.014
	Gamification	Maintenance stage	14.5	29.	-1.29	.206
Gamification x Gender	Gamification	Male	15.5	51.	-2.36	.016
	Gamification	Female	9.0	19.	-0.95	.412
Gender x Runner type	Gender	Single Runner	17.5	27.	-0.59	.571
	Gender	Team Runner	37.5	65.	1.10	.281
Gender x Stage of behavior change	Gender	Action stage	26.5	36.	0.59	.571
	Gender	Maintenance stage	19.5	47.	-0.99	.336
Gender x Gamification	Gender	Male	32.0	60.	-0.59	.596
	Gender	Female	21.0	31.	0.86	.461

Appendix G. A Summary of Hypotheses Testing Results

Table 22. A summary table of hypotheses testing results

Hypotheses testing results		**Supported**
H1	**Presence of social element will increase persuasive power**	
	a. Social elements ➔ Significant increase in the external motivation of single runners	Supported
	b. Social elements ➔ Significant increase in the internal motivation of single runners	Supported
	c. Social elements ➔ Significant increase in the satisfaction of single runners	Supported
	d. Social elements ➔ Significant increase in the number of running activities completed by single runners	Not supported
	e. Social elements ➔ Significant increase in the external motivation of team runners	Not supported
	f. Social elements ➔ Significant increase in the internal motivation of team runners	Supported
	g. Social elements ➔ Significant increase in the satisfaction of team runners	Not supported
	h. Social elements ➔ Significant increase in the number of running activities completed by team runners	Not supported
H2	**Persuasive elements will differently affect runners at different stages**	
	a. Persuasive elements ➔ Significant increase in the external motivation of runners at the maintenance stage	Supported
	b. Persuasive elements ➔ Significant increase in the internal motivation of runners at the maintenance stage	Supported
	c. Persuasive elements ➔ Significant increase in the satisfaction of runners at the maintenance stage	Supported
	d. Persuasive elements ➔ Significant increase in the number of running activities completed by runners at the maintenance stage	Partially supported
	e. Persuasive elements ➔ Significant increase in the external motivation of runners at the action stage	Not supported
	f. Persuasive elements ➔ Significant increase in the internal motivation of runners at the action stage	Supported
	g. Persuasive elements ➔ Significant increase in the satisfaction of runners at the action stage	Not supported
	h. Persuasive elements ➔ Significant increase in the number of running activities completed by runners at the action stage	Not supported
H3	**Presence of gamification will increase persuasive power**	
	a. Presence of Gamification ➔ Significant increase in the external motivation of runners	Supported
	b. Presence of Gamification ➔ Significant increase in the internal motivation of runners	Supported
	c. Presence of Gamification ➔ Significant increase in the satisfaction of runners	Not supported
	d. Presence of Gamification ➔ Significant increase in the number of running activities completed by runners	Partially supported

H4	**Persuasive elements will affect male runners and female runners differently**	
	a. Persuasive elements ➔ Significant increase in the external motivation of male runners	Supported
	b. Persuasive elements ➔ Significant increase in the internal motivation of male runners	Supported
	c. Persuasive elements ➔ Significant increase in the satisfaction of male runners	Not supported
	d. Persuasive elements ➔ Significant increase in the number of running activities completed by male runners	Not supported
	e. Persuasive elements ➔ Significant increase in the external motivation of female runners	Not supported
	f. Persuasive elements ➔ Significant increase in the internal motivation of female runners	Supported
	g. Persuasive elements ➔ Significant increase in the satisfaction of female runners	Not supported
	h. Persuasive elements ➔ Significant increase in the number of running activities completed by female runners	Not supported

REFERENCES

Adams, J., & White, M. (2005). Why don't stage-based activity promotion interventions work?. *Health education research*, *20*(2), 237-243.

Ahtinen, A., Mattila, E., Vaatanen, A., Hynninen, L., Salminen, J., Koskinen, E., & Laine, K. (2009, April). User experiences of mobile wellness applications in health promotion: User study of Wellness Diary, Mobile Coach and SelfRelax. In *Pervasive Computing Technologies for Healthcare, 2009. PervasiveHealth 2009. 3rd International Conference on* (pp. 1-8). IEEE.

Aitken, C. K., McMahon, T. A., Wearing, A. J., & Finlayson, B. L. (1994). Residential water use: predicting and reducing consumption1. *Journal of Applied Social Psychology*, *24*(2), 136-158.

Ajzen, I., & Fishbein, M. (1980). Understanding attitudes and predicting social. *Behaviour. Englewood Cliffs, NJ: Prentice-Hall*.

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, *50*(2), 179-211.

Ajzen, I., & Fishbein, M. (2004). Questions raised by a reasoned action approach: comment on Ogden (2003).

Allen, K. C. (2013). *Developing and testing smartphone game applications for physical activity promotion in adolescents* (Doctoral dissertation, Virginia Polytechnic Institute and State University).

Anderson, I., Maitland, J., Sherwood, S., Barkhuus, L., Chalmers, M., Hall, M., ... & Muller, H. (2007). Shakra: tracking and sharing daily activity levels with unaugmented mobile phones. *Mobile Networks and Applications*, *12*(2-3), 185-199.

Antin, J., & Churchill, E. F. (2011). Badges in social media: A social psychological perspective. In *CHI 2011 Gamification Workshop Proceedings (Vancouver, BC, Canada, 2011)*.

Aronson, E., & O'Leary, M. (1982). The relative effectiveness of models and prompts on energy conservation: A field experiment in a shower room. *Journal of Environmental Systems*, *12*(3), 219-224.

Arroyo, E., Bonanni, L., & Selker, T. (2005, April). Waterbot: exploring feedback and persuasive techniques at the sink. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 631-639). ACM.

Bakkes, S., Tan, C. T., & Pisan, Y. (2012, July). Personalised gaming: a motivation and overview of literature. In *Proceedings of the 8th Australasian Conference on Interactive Entertainment: Playing the System* (p. 4). ACM.

Bang, M., Torstensson, C., & Katzeff, C. (2006). The powerHhouse: A persuasive computer game designed to raise awareness of domestic energy consumption. In *Persuasive technology* (pp. 123-132). Springer Berlin Heidelberg.

Barnett, A., Cerin, E., & Baranowski, T. (2011). Active video games for youth: a systematic review. *Journal of Physical Activity and Health*, *8*(5), 724-737.

Berdichevsky, D., & Neuenschwander, E. (1999). Toward an ethics of persuasive technology. *Communications of the ACM*, *42*(5), 51-58.

Biddiss, E., & Irwin, J. (2010). Active video games to promote physical activity in children and youth: a systematic review. *Archives of pediatrics & adolescent medicine*, *164*(7), 664-672.

Biddle, S. J., Gorely, T., Marshall, S. J., Murdey, I., & Cameron, N. (2004). Physical activity and sedentary behaviours in youth: issues and controversies. *The Journal of the Royal Society for the Promotion of Health*, *124*(1), 29-33.

Cavallo, D. N., Tate, D. F., Ries, A. V., Brown, J. D., DeVellis, R. F., & Ammerman, A. S. (2012). A social media–based physical activity intervention: a randomized controlled trial. *American journal of preventive medicine*, *43*(5), 527-532.

Chen, J. (2007). Flow in games (and everything else). *Communications of the ACM*, *50*(4), 31-34.

Chen, J. H., Chi, P. P. Y., Hao-Hua Chu, P. P. Y., Chen, C. C. H., & Huang, P. (2010). A smart kitchen for nutrition-aware cooking.

Chittaro, L. (2001). Information visualization and its application to medicine. *Artificial Intelligence in Medicine*, *22*(2), 81-88.

Chiu, M. C., Chang, S. P., Chang, Y. C., Chu, H. H., Chen, C. C. H., Hsiao, F. H., & Ko, J. C. (2009, September). Playful bottle: a mobile social persuasion system to motivate healthy water intake. In *Proceedings of the 11th international conference on Ubiquitous computing* (pp. 185-194). ACM.

Chowdhury, S., & Endres, M. (2000). SELF-EFFICACY OF EMPLOYMENT OUTSIDE THE CURRENT ORGANIZATION: SOME SKILLS COULD BE DETRIMENTAL.

Cialdini, R. B. (2001). Harnessing the science of persuasion. *Harvard Business Review*, *79*(9), 72-81.

Consolvo, S., Everitt, K., Smith, I., & Landay, J. A. (2006, April). Design requirements for technologies that encourage physical activity. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 457-466). ACM.

Cornelli Sanderson, R. (2010). Towards a new measure of playfulness: The capacity to fully and freely engage in play.

Deman, J. (2014, March 14). NOAA: Winter 2013-2014 Among coldest on record in Midwest; Driest, warmest in Southwest. *The Weather Channel.* Retrieved from http://www.weather.com/news/winter-ncdc-state-climate-report-2013-2014-20140313

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining gamification. In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9-15). ACM.

Dutta-Bergman, M. J. (2005). Theory and practice in health communication campaigns: A critical interrogation. *Health communication*, *18*(2), 103-122.

Eastman, C., & Marzillier, J. S. (1984). Theoretical and methodological difficulties in Bandura's self-efficacy theory. *Cognitive Therapy and Research*, *8*(3), 213-229.

Ekelund, U., Åman, J., Yngve, A., Renman, C., Westerterp, K., & Sjöström, M. (2002). Physical activity but not energy expenditure is reduced in obese adolescents: a case-control study. *The American journal of clinical nutrition*, *76*(5), 935-941.

Epstein, L. H., Valoski, A. M., Vara, L. S., McCurley, J., Wisniewski, L., Kalarchian, M. A., ... & Shrager, L. R. (1995). Effects of decreasing sedentary behavior and increasing activity on weight change in obese children. *Health psychology*, *14*(2), 109.

Falciglia, G. A., & Gussow, J. D. (1980). Television commercials and eating behavior of obese and normal-weight women. *Journal of Nutrition Education*, *12*(4), 196-199.

Ferris, K. R. (1977). A test of the expectancy theory of motivation in an accounting environment. *Accounting review*, 605-615.

Fogg, B. J. (1999). Persuasive technologies. *Communications of the ACM*, *42*(5), 26-29.

Fogg, B. J. (2002). Persuasive technology: using computers to change what we think and do. *Ubiquity*, *2002*(December), 5.

Fogg, B. J., & Eckles, D. (Eds.). (2007). *Mobile persuasion: 20 perspectives on the future of behavior change* (Vol. 1). Standford, CA: Stanford Captology Media.

Fogg, B. J. (2009, April). A behavior model for persuasive design. In *Proceedings of the 4th international Conference on Persuasive Technology* (p. 40). ACM.

Foley, L., & Maddison, R. (2010). Use of active video games to increase physical activity in children: a (virtual) reality. *Pediatr Exerc Sci*, *22*(1), 7-20.

Foster, D., Lawson, S., Blythe, M., & Cairns, P. (2010, October). Wattsup?: motivating reductions in domestic energy consumption using social networks. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* (pp. 178-187). ACM.

Fried, Y., & Slowik, L. H. (2004). Enriching goal-setting theory with time: An integrated approach. *Academy of management Review*, *29*(3), 404-422.

Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., & Landay, J. A. (2009, April). UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1043-1052). ACM.

Gibson, F. K., & Teasley, C. E. (1973). The humanistic model of organizational motivation: A review of research support. *Public Administration Review*, 89-96.

Gist, M. E., & Mitchell, T. R. (1992). Self-efficacy: A theoretical analysis of its determinants and malleability. *Academy of Management review*, *17*(2), 183-211.

Gortmaker, S. L., Must, A., Sobol, A. M., Peterson, K., Colditz, G. A., & Dietz, W. H. (1996). Television viewing as a cause of increasing obesity among children in the United States, 1986-1990. *Archives of pediatrics & adolescent medicine*, *150*(4), 356-362.

Graf, D. L., Pratt, L. V., Hester, C. N., & Short, K. R. (2009). Playing active video games increases energy expenditure in children. *Pediatrics*, *124*(2), 534-540.

Graves, L., Stratton, G., Ridgers, N. D., & Cable, N. T. (2007). Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: cross sectional study. *Bmj*, *335*(7633), 1282-1284.

Hall, D. T., & Nougaim, K. E. (1968). An examination of Maslow's need hierarchy in an organizational setting. *Organizational behavior and human performance*, *3*(1), 12-35.

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *The Lancet*, *380*(9838), 247-257.

Hands, B., Larkin, D., Parker, H., Straker, L., & Perry, M. (2009). The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scandinavian journal of medicine & science in sports*, *19*(5), 655-663.

Heer, J., Bostock, M., & Ogievetsky, V. (2010). A tour through the visualization zoo. *Commun. ACM*, *53*(6), 59-67.

Hirsh, J. B., Kang, S. K., & Bodenhausen, G. V. (2012). Personalized persuasion tailoring persuasive appeals to recipients' personality traits.*Psychological science*, *23*(6), 578-581.

Hofstede, G. (1984). The cultural relativity of the quality of life concept. *Academy of Management review*, *9*(3), 389-398.

Hargie, O. (Ed.). (1997). *The handbook of communication skills*. Psychology Press.

IJsselsteijn, W., de Kort, Y., Midden, C., Eggen, B., & van den Hoven, E. (2006). Persuasive technology for human well-being: setting the scene. In *Persuasive technology* (pp. 1-5). Springer Berlin Heidelberg.

Intille, S. S., Kukla, C., Farzanfar, R., & Bakr, W. (2003). Just-in-time technology to encourage incremental, dietary behavior change. In *AMIA Annual Symposium Proceedings* (Vol. 2003, p. 874). American Medical Informatics Association.

Iso-Ahola, S. E., & Clair, B. S. (2000). Toward a theory of exercise motivation. *Quest*, *52*(2), 131-147.

Jafarkarimi, H., Sim, A. T. H., & Saadatdoost, R. (2012). A naive recommendation model for large databases. *International Journal of Information and Education Technology*, *2*(2), 216-219.

Kallehave, O., Skov, M. B., & Tiainen, N. (2010). Reducing the Paradox of Choice: Designing a Nutritious Persuasive Shopping Trolley.

Kamal, N., Fels, S., Blackstock, M., & Ho, K. (2011). VivoSpace: towards health behavior change using social gaming. In *Entertainment Computing–ICEC 2011* (pp. 319-330). Springer Berlin Heidelberg.

Kanfer, R. (1990). Motivation theory and industrial and organizational psychology.

Karanam, Y., Alotaibi, H., Filko, L., Makhsoom, E., Kaser, L., & Voida, S. (2014, September). Motivational affordances and personality types in personal informatics. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication* (pp. 79-82). ACM.

Katz-Navon, T., Naveh, E., & Stern, Z. (2007). Safety self-efficacy and safety performance: Potential antecedents and the moderation effect of standardization. *International journal of health care quality assurance*, *20*(7), 572-584.

Kazdin, A. E. (1978). Conceptual and assessment issues raised by self-efficacy theory. *Advances in behaviour research and therapy*, *1*(4), 177-185.

Kenrick, D. (2010). Rebuilding Maslow's pyramid on an evolutionary foundation. *Psychology Today: Health, Help, Happiness+ Find a Therapist. Retrieved July*, *16*, 2010.

Kessell, A. M. (2008). *Cognitive Methods for Information Visualization: Linear and Cyclical Events* (Doctoral dissertation, Stanford University).

Keyani, P., Hsieh, G., Mutlu, B., Easterday, M., & Forlizzi, J. (2005, April). DanceAlong: supporting positive social exchange and exercise for the elderly through dance. In *CHI'05 extended abstracts on Human factors in computing systems* (pp. 1541-1544). ACM.

Kim, C., Hwang, A., & Yoo, J. (2004). The impact of a stage-matched intervention to promote exercise behavior in participants with type 2 diabetes. *International Journal of Nursing Studies.* Vol.41. No.8. pp.833-841.

King, P., & Tester, J. (1999). The landscape of persuasive technologies. *Communications of the ACM*, *42*(5), 31-38.

King, W. J., & Ohya, J. (1996, April). The representation of agents: Anthropomorphism, agency, and intelligence. In *Conference Companion on Human Factors in Computing Systems* (pp. 289-290). ACM.

Hollenbeck, J. R., & Klein, H. J. (1987). Goal commitment and the goal-setting process: Problems, prospects, and proposals for future research. *Journal of Applied Psychology*, *72*(2), 212.

Knight, D., Durham, C. C., & Locke, E. A. (2001). The relationship of team goals, incentives, and efficacy to strategic risk, tactical implementation, and performance. *Academy of Management Journal*, *44*(2), 326-338.

Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., & Landay, J. A. (2009, April). UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1043-1052). ACM.

Lanningham-Foster, L., Foster, R. C., McCrady, S. K., Jensen, T. B., Mitre, N., & Levine, J. A. (2009). Activity-promoting video games and increased energy expenditure. *The Journal of pediatrics*, *154*(6), 819-823.

Latham, G. P., & Locke, E. A. (1991). Self-regulation through goal setting. *Organizational behavior and human decision processes*, *50*(2), 212-247.

Lau, A., & Vande Moere, A. (2007, July). Towards a model of information aesthetics in information visualization. In *Information Visualization, 2007. IV'07. 11th International Conference* (pp. 87-92). IEEE.

Lawley, J. (2013, August 17). *Fogg model of behavior change*. Retrieved from http://www.cleanlanguage.co.uk/articles/blogs/91/Fogg-Model-of-Behavior-Change.html

Leatherdale, S. T., & Wong, S. (2009). Peer Reviewed: Association Between Sedentary Behavior, Physical Activity, and Obesity: Inactivity Among Active Kids. *Preventing chronic disease*, *6*(1).

Leatherdale, S. T., Woodruff, S. J., & Manske, S. R. (2010). Energy expenditure while playing active and inactive video games. *American journal of health behavior*, *34*(1), 31-35.

Lee, B., Parr, C. S., Plaisant, C., Bederson, B. B., Veksler, V. D., Gray, W. D., & Kotfila, C. (2006). Treeplus: Interactive exploration of networks with enhanced tree layouts. *Visualization and Computer Graphics, IEEE Transactions on*, *12*(6), 1414-1426.

Lee, C., & Bobko, P. (1994). Self-efficacy beliefs: Comparison of five measures. *Journal of Applied Psychology*, *79*(3), 364.

Lenio, J. A. (2006). Analysis of the Transtheoretical Model of behavior change. *Journal of Student research*, *5*, 73-87.

Littell, J. H., & Girvin, H. (2002). Stages of Change A Critique. *Behavior Modification*, *26*(2), 223-273.

Liu, S., Helfenstein, S., & Wahlstedt, A. (2008). Social Psychology of Persuasion Applied to Human Agent Interaction.

Locke, E. A., Frederick, E., Lee, C., & Bobko, P. (1984). Effect of self-efficacy, goals, and task strategies on task performance. *Journal of applied psychology*, *69*(2), 241.

Locke, E. A., Chah, D. O., Harrison, S., & Lustgarten, N. (1989). Separating the effects of goal specificity from goal level. *Organizational Behavior and Human Decision Processes*, *43*(2), 270-287.

Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting & task performance*. Prentice-Hall, Inc.

Locke, E. A., & Latham, G. P. (1994). Goal setting theory. *Motivation: Theory and research*, 13-29.

Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American psychologist*, *57*(9), 705.

Locke, E. A., & Latham, G. P. (2006). New directions in goal-setting theory. *Current directions in psychological science*, *15*(5), 265-268.

Lurie, N. H., & Mason, C. H. (2007). Visual representation: Implications for decision making. *Journal of Marketing*, *71*(1), 160-177.

Lutfiyya, M. N., Garcia, R., Dankwa, C. M., Young, T., & Lipsky, M. S. (2008). Overweight and obese prevalence rates in African American and Hispanic children: an analysis of data from the 2003–2004 National Survey of Children's Health. *The Journal of the American Board of Family Medicine*, *21*(3), 191-199.

Mamykina, L., Mynatt, E., Davidson, P., & Greenblatt, D. (2008, April). MAHI: investigation of social scaffolding for reflective thinking in diabetes management. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 477-486). ACM.

Marcus, B. H., Selby, V. C., Niaura, R. S., & Rossi, J. S. (1992). Self-efficacy and the stages of exercise behavior change. *Research quarterly for exercise and sport*, *63*(1), 60-66.

Mattila, E., Korhonen, I., Lappalainen, R., Ahtinen, A., Hopsu, L., & Leino, T. (2008, August). Nuadu concept for personal management of lifestyle related health risks. In *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE* (pp. 5846-5850). IEEE.

McClelland, D. C. (1965). Toward a theory of motive acquisition. *American Psychologist*, *20*(5), 321.

McLeod, S. (2007). Maslow's hierarchy of needs. *Simply Psychology*.

Murcia, J. A. M., Galindo, C. M., & Pardo, P. M. (2008). Motivations and reasons for exercising in water: Gender and age differences in a sample of spanish exercisers. *International Journal of Aquatic Research and Education*, *2*(3).

MURPHY, E. C. S., Carson, L., Neal, W., Baylis, C., Donley, D., & Yeater, R. (2009). Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children. *International Journal of Pediatric Obesity*, *4*(4), 205-214.

Nelson, T., Megens, C., & Peeters, M. (2012). Bouncers: a design exploration into sharing and triggering personal activity amongst friends. *Persuasive Technology*, 33.

Net/Tech to unveil patented Hygiene Guard Hand-Washing Monitoring System at the National Restaurant Show. (1997, April 3). *The Free Library.* Retrieved July 21, 2014 from http://www.thefreelibrary.com/Net/Tech to unveil patented Hygiene Guard Hand-Washing Monitoring...-a019277592

Nevis, E. C. (1982). Cultural assumptions and productivity: the United States and China. *Sloan Management Review*, *24*(3), 17-29.

Munro, S., Lewin, S., Swart, T., & Volmink, J. (2007). A review of health behaviour theories: how useful are these for developing interventions to promote long-term medication adherence for TB and HIV/AIDS?. *BMC public health*, *7*(1), 104.

Ogden, C. L., Flegal, K. M., Carroll, M. D., & Johnson, C. L. (2002). Prevalence and trends in overweight among US children and adolescents, 1999-2000. *Jama*, *288*(14), 1728-1732.

Ogden, J. (2003). Some problems with social cognition models: a pragmatic and conceptual analysis. *Health Psychology*, *22*(4), 424.

Oinas-Kukkonen, H., & Harjumaa, M. (2009). Persuasive systems design: Key issues, process model, and system features. *Communications of the Association for Information Systems*, *24*(1), 28.

Pfaff, M. S., Drury, J. L., Klein, G. L., & More, L. D. (2010). Decision support for option awareness in complex emergency scenarios. In *3rd International Conference on Applied Human Factors and Ergonomics (AHFE)*.

Pfaff, M. S., Drury, J. L., Klein, G. L., More, L., Moon, S. P., & Liu, Y. (2010, November). Weighing decisions: Aiding emergency response decision making via option awareness. In *Technologies for Homeland Security (HST), 2010 IEEE International Conference on* (pp. 251-257). IEEE.

Pierce, W. D., & Cheney, C. D. (2013). *Behavior analysis and learning*. Psychology Press.

Pinto, B. M., Goldstein, M. G., Papandonatos, G. D., Farrell, N., Tilkemeier, P., Marcus, B. H., & Todaro, J. F. (2011). Maintenance of exercise after phase II cardiac rehabilitation: a randomized controlled trial. *American journal of preventive medicine*, *41*(3), 274-283.

Pinto, B. M., & Trunzo, J. J. (2005). Health behaviors during and after a cancer diagnosis. *Cancer*, *104*(S11), 2614-2623.

Plaisant, C. (2004, May). The challenge of information visualization evaluation. In *Proceedings of the working conference on Advanced visual interfaces* (pp. 109-116). ACM.

Polaine, A. (2005, November). The flow principle in interactivity. In *Proceedings of the second Australasian conference on Interactive entertainment* (pp. 151-158). Creativity & Cognition Studios Press.

Porat, A. B. (1977). Guttman scale test for Maslow need hierarchy. *The Journal of Psychology*, *97*(1), 85-92.

President's Council on Fitness, Sports & Nutrition. (2010). Facts & statistics about physical activity. Retrieved from http://www.fitness.gov/resource-center/facts-and-statistics/#footnote-2

Pinto, B. M., Goldstein, M. G., Papandonatos, G. D., Farrell, N., Tilkemeier, P., Marcus, B. H., & Todaro, J. F. (2011). Maintenance of exercise after phase II cardiac rehabilitation: a randomized controlled trial. *American journal of preventive medicine*, *41*(3), 274-283.

Prochaska, J. O., & Marcus, B. H. (1994). The transtheoretical model: applications to exercise.

Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American journal of health promotion*, *12*(1), 38-48.

Rauschenberger, J., Schmitt, N., & Hunter, J. E. (1980). A test of the need hierarchy concept by a Markov model of change in need strength. *Administrative Science Quarterly*, 654-670.

Raymond, M. A., Mittelstaedt, J. D., & Hopkins, C. D. (2003). When is a hierarchy not a hierarchy? Factors associated with different perceptions of needs, with implications for Standardization-Adaptation decisions in Korea. *Journal of Marketing Theory and Practice*, 12-25.

Redmond, B. F. (2010). Self-Efficacy Theory: Do I think that I can succeed in my work. *Work Attitudes and Motivation*.

Reeves, B., & Read, J. L. (2009). Total engagement: using games and virtual worlds to change the way people work and businesses compete. *New York, USA*.

Rodgers, W. M., Courneya, K. S., & Bayduza, A. L. (2001). Examination of the transtheoretical model and exercise in 3 populations. *American journal of health behavior*, *25*(1), 33-41.

Romero, N., Sturm, J., Bekker, T., De Valk, L., & Kruitwagen, S. (2010). Playful persuasion to support older adults' social and physical activities. *Interacting with Computers*, *22*(6), 485-495.

Russell, W. D., Dzewaltowski, D. A., & Ryan, G. J. (1999). The effectiveness of a point-of-decision prompt in deterring sedentary behavior. *American Journal of Health Promotion*, *13*(5), 257-259.

Salbe, A. D., Weyer, C., Harper, I., Lindsay, R. S., Ravussin, E., & Tataranni, P. A. (2002). Assessing risk factors for obesity between childhood and adolescence: II. Energy metabolism and physical activity. *Pediatrics*, *110*(2), 307-314.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology*, *57*(1), 1-29.

Senecal, S., & Nantel, J. (2004). The influence of online product recommendations on consumers' online choices. *Journal of retailing*, *80*(2), 159-169.

Sharma, M., & Kanekar, A. (2007). Theory of reasoned action & theory of planned behavior in alcohol and drug education. *Journal of alcohol and drug education*, *51*(1), 3.

Skinner, B. F. (2011). *About behaviorism*. Random House LLC.

Smith-Hunter, A., Kapp, J., & Yonkers, V. (2003). A psychological model of entrepreneurial behavior. *Journal of Academy of Business and Economics*, *2*(2), 180-192.

Soper, B., Milford, G. E., & Rosenthal, G. T. (1995). Belief when evidence does not support theory. *Psychology & Marketing*, *12*(5), 415-422.

Steinbeck, K. S. (2001). The importance of physical activity in the prevention of overweight and obesity in childhood: a review and an opinion. *Obesity reviews*, *2*(2), 117-130.

Steel, P., & König, C. J. (2006). Integrating theories of motivation. *Academy of Management Review*, *31*(4), 889-913.

Sutton, S. (2001). Back to the drawing board? A review of applications of the transtheoretical model to substance use. *Addiction*, *96*(1), 175-186.

Takama, Y., Dohi, H., & Ishizuka, M. (1998, July). A visual anthropomorphic agent with learning capability of cooperative answering strategy through speech dialog. In *Computer Human Interaction, 1998. Proceedings. 3rd Asia Pacific* (pp. 260-265). IEEE.

Tay, L., & Diener, E. (2011). Needs and subjective well-being around the world. *Journal of personality and social psychology*, *101*(2), 354.

Tosi, H. L., Rizzo, J. R., & Carroll, S. J. (2000). *Managing organizational behavior*. Oxford, England: Blackwell.

Tversky, B., Zacks, J., Lee, P., & Heiser, J. (2000). Lines, blobs, crosses and arrows: Diagrammatic communication with schematic figures. In *Theory and application of diagrams* (pp. 221-230). Springer Berlin Heidelberg.

Tversky, B. (2001). Spatial schemas in depictions. In *Spatial schemas and abstract thought* (pp. 79-111).

van Stralen, M. M., De Vries, H., Mudde, A. N., Bolman, C., & Lechner, L. (2009). Determinants of initiation and maintenance of physical activity among older adults: a literature review. *Health Psychology Review*, *3*(2), 147-207.

Vansteenkiste, M., & Sheldon, K. M. (2006). There's nothing more practical than a good theory: Integrating motivational interviewing and self-determination theory. *British journal of clinical psychology*, *45*(1), 63-82.

Wahba, M. A., & Bridwell, L. G. (1976). Maslow reconsidered: A review of research on the need hierarchy theory. *Organizational behavior and human performance*, *15*(2), 212-240.

Werner, P. (2004). Reasoned action and planned behavior. *Middle range Theories: Application to Nursing Research, Lippincott Williams and Wilkins, Philadelphia*, 125-147.

West, R. (2005). Time for a change: putting the Transtheoretical (Stages of Change) Model to rest. *Addiction*, *100*(8), 1036-1039.

Wong, F., Huhman, M., Asbury, L., Bretthauer-Mueller, R., McCarthy, S., Londe, P., & Heitzler, C. (2004). VERB™—a social marketing campaign to increase physical activity among youth. *Preventing Chronic Disease*, *1*(3).

World Health Organization (2014). Global Strategy on Diet, Physical Activity and Health. Retrieved from http://www.who.int/dietphysicalactivity/factsheet_inactivity/en/

Yi, J. S. (2007). Visualized decision making: Information visualization techniques to improve decision quality of nursing home choice. Presented at Brown Bag Event, GVU Center, Georgia Institute of Technology, Atlanta, Georgia, March 8, 2007.

CURRICULUM VITAE

Sung Pil Moon

EDUCATION

Ph.D., Informatics and Computing, Human-Computer Interaction (May 2015)
Indiana University, Indianapolis, IN, USA. Advisor. Dr. Mark Pfaff.
Dissertation: HamkeRun: Mobile infoVis app towards sustainable motivation in a context of running
Minor: Computer Science (Individualized minor)

M.S., Information Technology (August, 2006)
Carnegie Mellon University, Pittsburgh, PA, USA

B.S., Computer Engineering (February, 2004)
Soongsil University, Seoul, Korea Republic

RESEARCH AND PROFESSIONAL EXPERIENCE

Graduate Research Assistant, Indiana University, Indianapolis (2008 - 2014)

- HamkeRun (Dec.2012 – Dec.2014)
  - Developed a mobile information visualization application which is intended to increase motivation to run more and more frequently in a running context
  - Utilized motivational elements of information visualization, gamification, and social competition / cooperation.

- Shared Patient Decision Space project (Sep.2012 – Aug.2013)
  - Developed a decision-making tool to enable both doctor and patient to attain shared decision space, deeper levels of option awareness and choose a robust option via visualizations of the decision space.
  - Funded by MITRE research Corporation (www.mitre.org)
  - Project number: 51MSR605-BA and 51MSR603-AA
  - Take a role for UI, visualization, front-end development and usability

- GRAPPA Decision Space information development project (Sep.2008 – Mar.2011)
  - Developed a decision space information visualization tool which is a model-based simulator to aid first emergency responder providing visualization of multiple decision options for more accurate and confident decisions.
  - Funded by MITRE research Corporation (www.mitre.org)
  - Project number: 43MSR001-EA, 45MSR026-FA
  - Took a role for UI, front-end side development and usability

- Top Health Trends project (Nov.2011 – June 2012)
  - Developed an information visualization tool showing local health-related Twitter trends to aid daily jobs of health-related experts.
  - Collaborated with MESH coalition (www.meshcoalition.org)
  - Took a main role in developing UI, front-end, collecting requirements, and conducting usability tests

- ANRORA (Aural Navigation Flow On Rich website Architecture) project (Sep.2012 – Jan.2013)
  - A NSF-funded project investigating linkless navigation strategy as a new way to increase mobile user experience while on-the-move.
    Developed an interactive mobile prototype (both in high fidelity and android version) and conducted usability tests

- MARVAND project (Nov.2012 – Feb.2013)
  - Developed a mobile application supporting disaster relief activities for onsite volunteers after natural disaster.
  - Took a main role in developing UI, front-end side, collecting user / system requirements, and conducting usability tests

Teaching Assistantship, Carnegie Mellon University, Pittsburgh, PA, USA. **(2006-2008)**
- Robot to the Rescue (RttR) class, Institute for Software Research (ISR)
  - Led a course and offered a guidance of general introduction of robotics, and developed a simulator with C#-based Microsoft Robotics Studio framework to communicate between mechanical devices and simulation services

Web developer, Webtown Company, Cheju City, Korea (1997-1998)
- Worked as a developer for e-business solutions, and as a web designer
- Developed Java-based web application framework and testing tool

PUBLICATION AND POSTERS

Moon, S. P., Liu, Y., Entezari, S., Pirzadeh, A., Pappas, A., & Pfaff, S. M. (May, 2013). Top Health Trends: An information visualization tool for awareness of local health trends. *10th International Conference on Information Systems for Crisis Response and Management (ISCRAM'13)*. Baden-Baden, Germany, May 12-15.

Pfaff, M. S., Klein, G. L., Drury, J. L., Moon, S. P., Liu, Y., & Entezari, S. O. (2012). Supporting complex decision making through option awareness. *Journal of Cognitive Engineering and Decision Making, Advance online publication*. doi: 10.1177/1555343412455799

Liu, Y., Moon, S. P., Pfaff, M. S., Drury, J. L., & Klein, G. L. (2011). Collaborative option awareness for emergency response decision making. Paper presented at the 8th *Annual International Conference on Information Systems for Crisis Response and Management (ISCRAM)*, Lisbon, Portugal, May 2011.

Pfaff, M. S., Drury, J. L., Klein, G. L., More, L. D., Moon, S. P., & Liu, Y. (2010). Weighing decisions: Aiding emergency response decision making via option awareness. *Proceedings of the 2010 IEEE International Conference on Technologies for Homeland Security (HST)*, 251-257.

Posters:
Moon, S. P., Liu, Y., and Powit, R. (2013, April). MARVAND: Mobile application for relief volunteering activity after natural disaster. Poster presented at the IUPUI Research Day 2013, Indianapolis, IN.

Bolchini, D., Rohani Ghahari, R., George-Palilonis, J., Moon, S.P., Archibald, C., & Kaser, L. (2012, November). Eyes-free web browsing with linkless navigation. IUPUI Innovation to Enterprise Showcase & Forum, IUPUI Campus Center, Indianapolis (IN), November 28, 2012.

Pfaff, M.S., Liu, Y., Moon, S. P., Entezari, S. O (2012, May). Effects of human-computer trust on collaborative decision making in a simulated emergency response. Poster presented at the 24th Annual Convention of the Association for Psychological Science, Chicago, IL.

Pfaff, M.S., Moon, S. P., & Liu, Y. (2010, April). The GRaPPa lab: Supporting team decision making in complex environments. Poster presented at the IUPUI Research Day, Indianapolis, IN.

Luther, J., Moon, S. P., Davide, D., & Faiola, A. (2009, November). Advancing paper-in-screen prototyping: Evaluating and interacting with digital sketched designs. Presented at 2009 Indiana World Usability Day, Indianapolis, IN.

HONORS AND AWARDS

Graduate Research Assistantship (2008-2014)
Indiana University, Indianapolis, USA

Scholarship for Talented Alumni Students (2012-2013)
Soongsil University, Seoul, Korea

Scholarship for Talented Student (2005-2006)
Ministry of Commerce, Industry and Energy of Korea

HCI AND TECHNICAL SKILLS

Design Methods
User-centered design, participatory design, ideation, affinity diagramming, scenarios, personas, information architecture, experience prototyping, technology probes

User Research
Ethnography, contextual inquiry, focus group, experience sampling method, usability testing, heuristic analysis, GOMS, cognitive walkthrough, wizard of OZ, survey design & data analysis

Prototyping
Sketching, low/mid/high fidelity prototyping, paper prototyping, experience prototyping, Flash, Photoshop, Balsamiq, Fluid UI

Development
Java (SCJP; Sun Certified Java Programmer), Javascript, HTML5, CSS, XML, jQuery Mobile, C#, C/C++, Adobe Flex web / mobile programming, Actionscipt, Map SDKs (GoogleMap, MapQuest, ESRIMap), MySQL, Kinvey (BaaS)

PATENT

System and Method for Producing Video Map
Attorney Docket Number N&N-114US, Application Number: 12258709