MODEL, FRAMEWORK, AND PLATFORM OF HEALTH PERSUASIVE SOCIAL NETWORK

by

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Submitted to the Graduate Faculty of

School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2013

UNIVERSITY OF PITTSBURGH
SCHOOL OF HEALTH AND REHABILITATION SCIENCES

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Persuasive technology (PT) has the potential to support individuals to perform self-management and social support as a part of health behavior change. This has led a few researchers in the intersection of the areas of health behavior change and software engineering to apply behavior change and persuasion theories to software development practices, enabling them to create innovative design principles and development-evaluation frameworks. Unfortunately these are too general for designing and evaluating health PT. Therefore, this dissertation proposes a model, framework, and platform of PT specifically designed for health intervention. The model and framework inform *what, why, and how conceptually* the suggested and required health behavior change strategies should be transformed into system features; and the platform explains *how technically* the transformation should be done. The platform includes functional requirements and provides most of the basic and standard computer code to develop the system features of such PT.

The model, framework, and platform were designed to work with various health behavior change programs. Nevertheless, in this dissertation, they support health behavior change for physical activity. As an implementation of and tool to evaluate the model, framework, and platform, a technology called Persuasive Social Network for Physical Activity (PersonA) is introduced. PersonA is a combination of automatic input of physical activity data, a smart phone, and social networking. Two systems (SocioPedometer and PAMS) as leverages of PersonA have been developed and evaluated.

The model, framework, and platform were evaluated based on the results of SocioPedometer's usability testing and 4-week trials (n=14) and on PAMS's usability testing (n=5). The results suggest that the systems were usable and accessible and that users were satisfied and enjoyed using it. Additional evaluations to the model and framework were conducted with the main purpose of eliciting users' preferences with respect to the characteristics and system features proposed in the model and framework. They rated most of the characteristics as extremely important (average 4.27 of a 5.00 maximum) and most of the system features as very important (average of 4.09). The platform allowed the two systems to be easily developed by customizing the data input and information presented.

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PREFACE

First of all, I would like to say *Alhamdulillah*… for allowing me to be where I am here right now.

I could not have completed this dissertation without the inspiration, encouragement, and support of many people. First, I would like to thank Dr. Bambang Parmanto, my advisor and dissertation committee chair, for his endless advice, guidance, and support in the last four years. I will always remember the support and guidance that helped polished my skill, in both my academic and professional life, throughout my graduate studies at Pitt. Also, I would like to thank my advisory committee members: Dr. Robert Branch, Dr. Dan Ding, and Dr. Diane Helsel. Their participation in this dissertation has been vital and generous. Their comments have helped me to shape and refine my research in deep and lasting ways ever since my proposal defense.

My thanks must also go to the Health and Rehabilitation (HaRI) laboratory members who have providing me with valuable comments, and being both good friends and teammates. I would also like to thank members of the Human Engineering Research Lab (HERL) of VA Healthcare Pittsburgh for helping me conduct my study with a special population, wheelchair users with spinal cord injury (SCI). The study gave me not only research data but also long-life lessons in understanding and treating people with special needs.

I would also like to take this opportunity to express my love and respect to my parents and families in Indonesia. My parent, Abdul Jalil and Nurochmi, who have the greatest influence in my life, who have been exceptional role models, and who have given unending understanding, patience, support, and love to me. To them, I owe a heartfelt thank you. I also owe my gratitude to my brothers and sisters: Arif Rahman, Murofik Urizal, Nurhidayah, and Nurul Mahabah. I'm also very thankful to my family-in-law who have been very supportive in the last five years. They all

have been great sources of the love, encouragement, and enlightenment that have kept me going over the study duration.

Thank you to all of my sincere friends, especially the Indonesian and Pengajian Community in Pittsburgh, for welcoming and supporting me in many ways.

I am pleased to thank my daughter –a special gift given during my study– Alicia Ayubi, who is also very independent at her age and allowed for a comfortable environment where I could peacefully study and write. Finally, a special thanks goes to my lovely wife, Tian Kinasih, who has been very helpful, responsible, patient, and understanding. She has provided me with necessary love, inspiration, assistance, support, and encouragement since getting married.

This work is partly funded by the following grants: Grant #R25 RR023274-03 from the National Center for Research Resources (NCRR), National Institutes of Health (NIH), United States of America (USA); Grant #IIS-0938393 from the National Science Foundation (NSF), USA; Grant #1R21HD071810-01A1 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), National Institutes of Health (NIH); Grant # SC090323 from the Department of Defense (DOD), USA; and a Scholarship from the Ministry of Education, The Republic of Indonesia.

1.0 INTRODUCTION

1.1 BACKGROUND

Many health problems are associated with high-risk behaviors such as lung cancer with smoking, obesity with overeating, sexually transmitted diseases (STD) with unprotected sexual activity, or obesity with physical inactivity. As the influence of prevention strategies within the health services has increased, behavior change from high risk to healthy behavior, in addition to clinical intervention, has become a central objective of health intervention. Health behavior change[1] may happen for many reasons. Generally, factors that determine behavior change can be classified as internal or external determinants. A person perceiving that physical activity and a diet program are essential for her/his health will be more likely to engage in physical activity and a diet program. Her/his knowledge and feelings are an internal determinant. Another person may consistently go to the gym because of the influence of a spouse or friends. Suggestions or examples from her/his spouse and friends are considered external determinants.

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[1] Health behavior change refers to the motivational, volitional, and actional processes of abandoning such health-compromising behaviors in favor of adopting and maintaining health-enhancing behaviors.

One way to strengthen the internal determinants for behavior change is education and empowerment. Education and empowerment enable individuals to understand the relationships between their health status and behavioral and/or environmental factors (e.g. diet, physical activity, social influence, and so forth) so that they are able to make personal informed decisions about actions and behaviors that may affect their health status. In addition, this education and empowerment will make them less dependent on services and recommendations from health practitioners, which is important as self-care decisions are often required of patients[2] facing a complex treatment plan due to serious and chronic conditions. This concept of education and empowerment is recognized as self-management[3].

Researchers in social sciences agree that, along with implementing self-management in health intervention, patients must be motivated to adhere to a regimen through monitoring, motivation, and support from health care professionals (Han, 2011), family, and peers. Moreover, sharing experiences with and receiving support from family and peers may ensure successful change. This positive influence from others that supports certain desired behavior is widely recognized as social support[4]. In the last decade, these two strategies —self-management and social support— have been the primary focus of behavior change programs.

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[2] In this document, 'patient' is used to refer to both patients (in the medical field) and clients (in the rehabilitation field) as persons who receive medical or rehabilitation services.

[3] In this document, 'self-management' always refers to health self-management unless stated otherwise.

[4] In this study, the term of 'social influence', 'social support', and 'social network' are sometimes interchangeable depending on the context because there is intersection among those, even though sometimes the three terms refer to different things. 'Social influence' refers to the effect of others on one person that can be defined by observed or

At the same time, advances in technologies —including information technology— have the potential to support individuals to perform self-management and/or social support as a part of a health behavior change program. The kind of technology designed to change behaviors of the users through persuasion and social influence, but not through coercion, is broadly recognized as persuasive technology (BJ. Fogg, 2003). Health intervention is one area where persuasive technology could be especially useful as behavior change becomes a central in health intervention. Therefore, a few researchers in the intersection area of health behavior change and software engineering have been trying to apply behavior change theories, combined with persuasion theories, to software development practices by proposing design principles and development-evaluation frameworks. Those principles and frameworks include Functional Triad and Design Principle (BJ. Fogg, 2003), Persuasion Theories and IT Design (Marja & Oinas-Kukkonen, 2007), the Eight-Step Design Process (BJ Fogg, 2009b), Persuasive System Design (Oinas-Kukkonen Harri & Harjumaa, 2009), Framework for Health Behavior Change through Social Media (Kamal, Fels, & Ho, 2010), and Five Strategies for Supporting Healthy Behavior Change (Medynskiy, Yarosh, & Mynatt, 2011).

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reported content or by the perceived support given to a person. These concepts are best measured by observations and reports or by scores of perceived support. Not all social influence is equally helpful. When the term ‘social support’ is used, a positive influence supporting certain wanted behavior is implicated. ‘Social pressure’ is sometimes used for positive (wanted) but more often negative (unwanted) influences enhancing or rather inhibiting a certain wanted behavior. ‘Social network’ refers to a web of social relationships and social linkages. This is best measured through enumeration, or quantitative scoring of its size, the number or density of social support sources, and persons around a person.

All the aforementioned frameworks and principles provide useful means for understanding persuasive technology, but unfortunately these seem to be too general as development and evaluation guidelines for health persuasive technology. Only two include the health behavior change context to some extent (Framework for Health Behavior Model and Five Strategies for Supporting Healthy Behavior Change); none provides technical platforms; and only the Framework for Health Behavior Model partly relates to utilizing the potential of currently available technologies in supporting health behavior change. A comparison among the aforementioned frameworks and principles is summarized in Table 1-1.

Table 1-1. Six Proposals of Design Principle and the Health Persuasive Social Network

Literatures	Type	Association with fundamental theories in Health Behavior Change	Include health intervention context	Utilize currently available technology (Sensor, Smartphone, SNS)	Provide technical platform
Functional Triad and Design Principles	Conceptual	Yes	No	No	No
Eight-step Design Process	Practical	No	No	No	No
Persuasive Theories and IT Design	Practical	Yes	No	No	No
Persuasive System Design	Conceptual & Practical	Yes	No	No	No
Framework for Health Behavior Change through Social Media	Conceptual	Yes (general)	Yes	Yes (SNS)	No
Five Strategies for Supporting Healthy Behavior Change	Practical	No	Yes	No	No
Health Persuasive Social Network*	**Conceptual & Practical**	**Yes**	**Yes**	**Yes (Sensor, Smartphone, and SNS)**	**Yes**

*This Dissertation

1.2 RESEARCH QUESTION

A conclusion drawn from the summary in Table 1-1 is that a complete and detailed conceptual and practical guideline to develop and evaluate health persuasive technology is currently not available and the role it can play in health behavior change is not well defined. The works presented in this dissertation are an attempt to fill this gap as they inform what the characteristics of a technology that can support health behavior change, how to develop such technology, and what materials needed to develop such technology.

Therefore the focus of this dissertation is to develop and evaluate a complete and detailed guideline for developing and evaluating a persuasive technology that can support self-management and social support practices in health behavior change. This persuasive technology conceptually will be defined as a Health Persuasive Social Network (HPSN). The seven following specific aims are designed to achieve this research goal:

Aim 1. To develop a model[5] of persuasive social network for health

The model informs the characteristics of tools/systems/applications that can facilitate and support the users to perform self-management and social support practices as a part of health behavior change. The characteristics were distilled from the research literature on fundamental theories and studies related to health behavior change and fundamental

[5] Model refers to a simpler representation of persuasive social network from perspectives of health behavior change strategies (self-management and social support) and technology.

theories relating technology to behavioral change. The model also informs the position of each characteristic in the context of health intervention strategies and currently available technologies. These two models are combined into one package and called as Health Persuasive Social Network Model (The HPSN model).

Aim 2. To develop a guideline for designing and evaluating health persuasive social network

The guideline informs how the suggested health behavior theories and strategies should be translated into detailed tool/system/application specifications. The guideline provides checklist or rules of thumbs rather than systematic design methods to develop a persuasive technology for health intervention. It also discusses how to evaluate the technology and describes what kind of content and system functionalities and features may be found at the final product of a health persuasive social network. The guideline was distilled from a literature and analytical study on health behavior intervention, persuasive technology, software engineering, and current technologies that have potentials for promoting healthier behavior. This development-evaluation guideline is called as Health Persuasive Social Network Framework[6] (The HPSN Framework).

Aim 3. To develop a communication platform bridging sensing technologies, smart phones, health portals, and social network sites.

One of the most important strategies on persuasiveness is simplicity. Hence to simplify data transmission among current technologies potentially combined in persuasive solution, an integrated communication platform was developed. The communication platform is an

[6] In this document, 'framework' always refers to 'practical framework', instead of 'conceptual framework' or 'IT related technical framework' unless stated otherwise.

underlying infrastructure (computer code) on which data can be transferred among the technologies (sensors, smart phones, secure servers, and Facebook). This platform is called The HPSN Communication Platform.

Aim 4. To develop an application platform of health persuasive social network

Based on the HPSN Model and Framework, ready-to-use and reusable components of the functions/features of a persuasive social network system were designed and implemented. Those components include libraries, classes, database, and logical infrastructure. The ready-to-use and reusable components are called as The HPSN Application Platform. Utilizing the platform, application developers do not need to build a persuasive technology from the scratch.

Aim 5. To customized the HPSN Platform[7] into systems promoting physical activity

The HPSN platform both the communication and application were customized into two ready to use Android mobile applications for PA promotion. The systems are called as The HPSN systems.

Aim 6. To evaluate whether all pre-designed requirements implemented in the HPSN system are accessible, usable, and persuasive to users.

A cognitive walkthrough usability inspection was conducted where users tested the HPSN system by performing a set of tasks. The evaluation was conducted iteratively, using the feedback on usability and accessibility issues of the prototype to improve subsequent designs. In this process, subjects were asked to perform a number of tasks using a "think

[7] "Platform" refers to both communication platforms and application platforms.

aloud" method. Once the think aloud process is complete for each task, investigators ask follow-up questions.

Aim 7. To evaluate the important level of characteristics proposed in the HPSN model as well as design principles proposed in the HPSN framework.

A survey was conducted to get users preference to the characteristics proposed in the HPSN model and design principles proposed in the HPSN framework. The participants of the survey were subjects of the HPSN system evaluations.

1.3 PHYSICAL ACTIVITY AS THE CASE

This dissertation is specifically concerned with supporting health behavior change as it relates to physical activity because regular physical activity is critical to everyone's physical and psychological health. Considerable evidence has been accumulated to support the hypothesis that a moderate level of physical activity (PA) reduces the risks of coronary heart disease (Blair et al., 1996; Thompson, 2003; Thompson et al., 2007) and virtually all causes of mortality. Physical inactivity is also considered a risk factor of hypertension and smoking (Fletcher et al., 1992), stroke (Hu et al., 2000), cancer (Verloop, Rookus, van der Kooy, & van Leeuwen, 2000), non-insulin dependent diabetes (Brancati, Kao, Folsom, Watson, & Szklo, 2000), and osteoporosis (Milgrom et al., 2000). As a result, the Surgeon General (US Department of Health and Human Services, 1996) and the US Centers for Disease Control and Prevention (CDC) have developed guidelines[8] to quantify the amount of physical activity required for health benefits (Pate et al., 1995). The guideline was then updated by several recommendations: PA Recommendation[9] from the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) (Haskell et al., 2007), Updated PA Recommendation[10] from the ACSM and the AHA (Nelson et

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[8]The guidelines state that, to maintain health, individuals with no known cardiovascular disease should accumulate at least 30 minutes of physical activity of at least moderate intensity for 5 or more days per week, or they should accumulate at least 20 minutes of vigorous-intensity aerobic physical activity 3 or more days per week.

[9] To promote and maintain health, all healthy adults aged 18 to 65 years need moderate-intensity aerobic (endurance) physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week. Combinations of moderate- and vigorous-intensity activity can be performed to meet this recommendation. For example, a person can meet the recommendation by walking briskly for 30 min twice during the week and then jogging for 20 min on two other days. Moderate-intensity aerobic activity, which is generally equivalent to a brisk walk and noticeably accelerates the heart rate, can be accumulated toward the 30-min minimum by performing bouts each lasting 10 or more minutes. Vigorous-intensity activity is exemplified by jogging, and causes rapid breathing and a substantial increase in heart rate. In addition, every adult should perform activities that maintain or increase muscular strength and endurance a minimum of two days each week. Because of the dose-response relation between physical activity and health, persons who wish to further improve their personal fitness, reduce their risk for chronic diseases and disabilities or prevent unhealthy weight gain may benefit by exceeding the minimum recommended amounts of physical activity.

[10] The recommendation for older adults is similar to the updated ACSM/AHA recommendation for adults, but has several important differences including: the recommended intensity of aerobic activity takes into account the older adult's aerobic fitness; activities that maintain or increase flexibility are recommended; and balance exercises are recommended for older adults at risk of falls. In addition, older adults should have an activity plan for achieving recommended physical activity that integrates preventive and therapeutic recommendations. The promotion of

al., 2007), and the 2008 PA Guidelines[11] for Americans (Haskell, et al., 2007; Nelson, et al., 2007; US Department of Health and Human Services, 2008). Unfortunately, despite the well-known numerous benefits of PA and well-published exercise guidelines, only 38% of US adults engage in regular leisure-time PA, and at least 25% were completely inactive in 2002-2004 (Adams & Schoenborn, 2006). Those numbers decreased to 30% engaging in regular leisure-time physical activity and at least 40% being completely inactive in 2005-2007 (Schoenborn & Adams, 2010). Another unfortunate fact is that most individuals who do begin exercise programs do not continue (Castro & King, 2002).

As an implementation of and a tool to evaluate the model, framework, and platform presented, this dissertation introduces a persuasive technology called Persuasive Social Network for Physical Activity (PersonA). PersonA[12] is a combination of automatic input of physical activity

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physical activity in older adults should emphasize moderate-intensity aerobic activity, muscle-strengthening activity, reducing sedentary behavior, and risk management.

[11] Children and adolescents should do 60 minutes (1 hour) or more of physical activity daily. 1) Aerobic: Most of the 60 or more minutes a day should be either moderate- or vigorous-intensity aerobic physical activity, and should include vigorous-intensity physical activity at least 3 days a week. 2) Muscle-strengthening: As part of their 60 or more minutes of daily physical activity, children and adolescents should include muscle-strengthening physical activity on at least 3 days of the week. 3) Bone-strengthening: As part of their 60 or more minutes of daily physical activity, children and adolescents should include bone-strengthening physical activity on at least 3 days of the week.

[12] 'PersonA' and 'Health Persuasive Social Network' and 'HPSN' are sometimes interchangeable depending on the context but 'PersonA' is specifically used to refer to a technical implementation or technical term of 'Health Persuasive Social Network' or 'HPSN'. 'PersonA' is also used as a conceptual term of 'Health Persuasive Social Network' that is used in the physical activity context.

data, a smart phone, and social networking (Ayubi & Parmanto, 2012). PersonA is designed to work on various health behavior change programs that leverage self-management and social support as the main strategies (Ayubi & Parmanto, 2012; Ding, Ayubi, Shivayogy, & Parmanto, 2012). PersonA is designed with the self-management and social support capabilities required to promote PA. Those capabilities were proposed based on an analytical study of theories and models in the area of behavior change, at the intersection of behavior change and technology, and in the area of technology development. Technically, PersonA is implemented to intelligently and automatically receive raw PA phenomena from the sensors, calculate the data into meaningful PA information, store the information on a secure server, and show the information to the users as persuasive and real-time feedback or publish the information to a social network system (SNS) for further social support purposes.

The first leverage of PersonA is an implementation of a monitoring and sharing technology called Physical Activity Monitoring and Sharing Platform (PAMS). PAMS was designed especially to capture physical activities that are part of the lifestyle of manual wheelchair users and to motivate them to be physically active via web-based or mobile social networking applications (Ding, et al., 2012). This implementation was motivated by research that have shown that people with physical disabilities, especially those who rely on manual wheelchairs as their primary means of mobility, are less likely to be physically active when compared to the able-bodied population (A. C. Buchholz, McGillivray, & Pencharz, 2003; van den Berg-Emons et al., 2008). Low levels of PA in this population have been associated with decreased aerobic capacity, muscular strength and endurance, and flexibility, all of which have the potential for restricting their functional independence and increasing their risks for chronic diseases and secondary complications (Fernhall, Heffernan, Jae, & Hedrick, 2008). In fact, this population reports a high number of chronic conditions (e.g., diabetes mellitus and cardiovascular disease) and secondary complications (e.g., fatigue, weight gain, pain, and depression) (Martin Ginis, Jetha, Mack, & Hetz, 2010; Tawashy, Eng, Lin, Tang, & Hung, 2009; Workshop on Disability in America, 2006). Last of all, wheelchair users also face more barriers in participating in regular PA than the general population (Kerstin, Gabriele, & Richard, 2006; van der Ploeg et al., 2008; Warms, Belza, & Whitney, 2007). In addition to the barriers related to their physical limitations such as pain, lack of energy, and lack of accessible facilities and exercise equipment, several studies also indicated that lack of social support from friends and family is an especially important determinant of PA participation for this population (van der Ploeg, et al., 2008; Warms, et al., 2007).

As the second leverage, PersonA is implemented in the promotion of PA using a smartphone-based pedometer application called SocioPedometer. SocioPedometer is used to attract users to have more physical activity in terms of steps that they take every day. The implementation is mainly motivated by the fact that walking or running is the easiest, cheapest, and safest PA that general population usually do, *yet* it has a positive impact on overall health outcomes (Bernsen & Nagelkerke, 2007; Johnson et al., 2007; Morio, Nicol, Barla, Barthelemy, & Berton, 2011; T. C. Smith, Wingard, Smith, Kritz-Silverstein, & Barrett-Connor, 2007). This implementation was also inspired by the public acceptance of a guideline of "10,000 steps/day" as the benchmark for an active lifestyle (Tudor-Locke & Bassett, 2004). Aside from criticism that the number suggested by the guideline may not be suitable for the elderly, people with mobility problems, or people with chronic diseases; or that this number is too low for the younger population, this number is still a very clear target that people can easily measure.

1.4 DISSERTATION OUTLINE

This report begins with an introduction to this dissertation (Chapter 1). It is followed by a literature review of fundamental theories referred to in this dissertation (Chapter 2). The literature review ends with an analysis of correlations between self-management, social support, and persuasive technology in health intervention and rehabilitation. It is followed by an analysis of the currently available advanced technologies that can be potentially combined and used to persuade people to perform desired health behavior change (Chapter 3). Chapter 4 then discusses the Health Persuasive Social Network model. Chapter 5 describes the frameworks of the Health Persuasive Social Network. Chapter 6 highlights an analysis and design of the platform of the Health Persuasive Social Network and its implementation in two cases and two systems. The two following chapters present the evaluation of the two PersonA systems (Chapter 7 for PAMS and Chapter 8 for SocioPedometer). Chapter 9 reports the evaluation of the PersonA models, framework, and platform in light of the evaluations reported in Chapter 7 and 8. Chapter 10 summarizes the overall conclusions of this research, which are followed by the contribution of this research and opportunities for future work. This dissertation outline is illustrated in the following Figure 1-1.

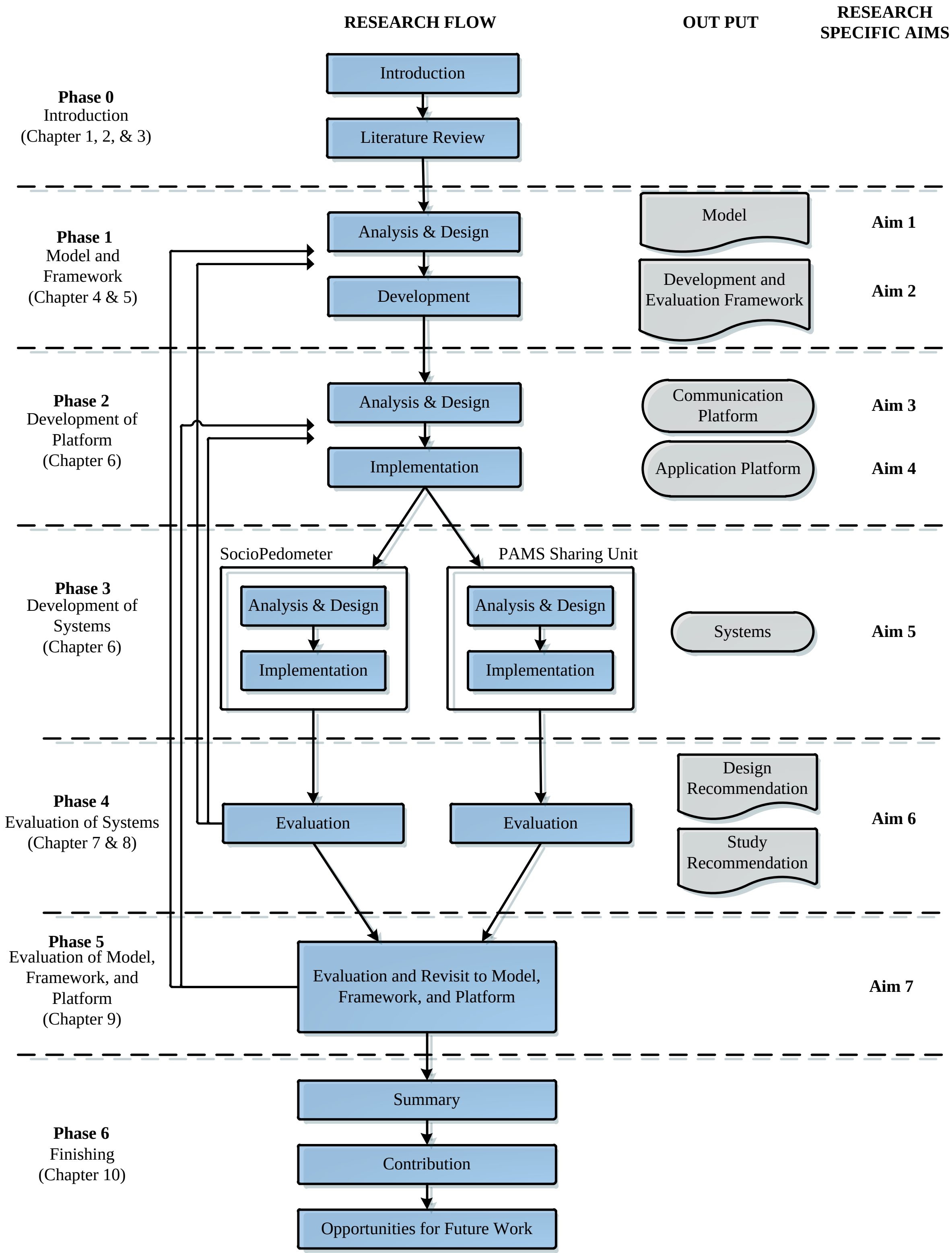

Figure 1-1. Roadmap of Dissertation

2.0 THEORY

The analysis led to the design of HPSN was informed by several theories and models, including theories and models in the behavior change area, those at the intersection of behavior change and technology, and those in technology development area. The theories in behavior change area include The Health Belief Model (HBM), Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) by Fishbein & Ajzen (1975, 1980), The Elaboration Likelihood Model (ELM) by Petty & Cacciopo (1980s), Social Cognitive Theory (SCT) by Bandura (1977-2001), and Uchino's Social Support and Physical Health Link (2006). The theories and models in the intersection between behavior change and technology include the Use and Gratification Theory (UGT), Common Bond and Common Identity Theory, and Technology Acceptance Model (TAM) by Davis and Bagozzi (1989, 1992), The Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003), and the Fogg Behavioral Model (FBM) (2009). Those theories in health behavior change and at the intersection of health behavior change and technology development are mainly referred to when discussing the design of the PersonA model. When discussing the design and evaluation of the PersonA framework and platform, the following theories and models in technology development are referred to: the Fogg Functional Triad and Design Principle by Fogg (2003), the Fogg Eight-Step Design Process by Fogg (2009), Persuasion System Design (PSD) by Oinas-Okkunen and Harjumaa (2009), and System Development Life-cycle (SDLC) with Waterfall Model and its dependents originally proposed by Royce (1970). The correlation between these theories and HPSN models, framework, and platforms is depicted in Figure 2-1.

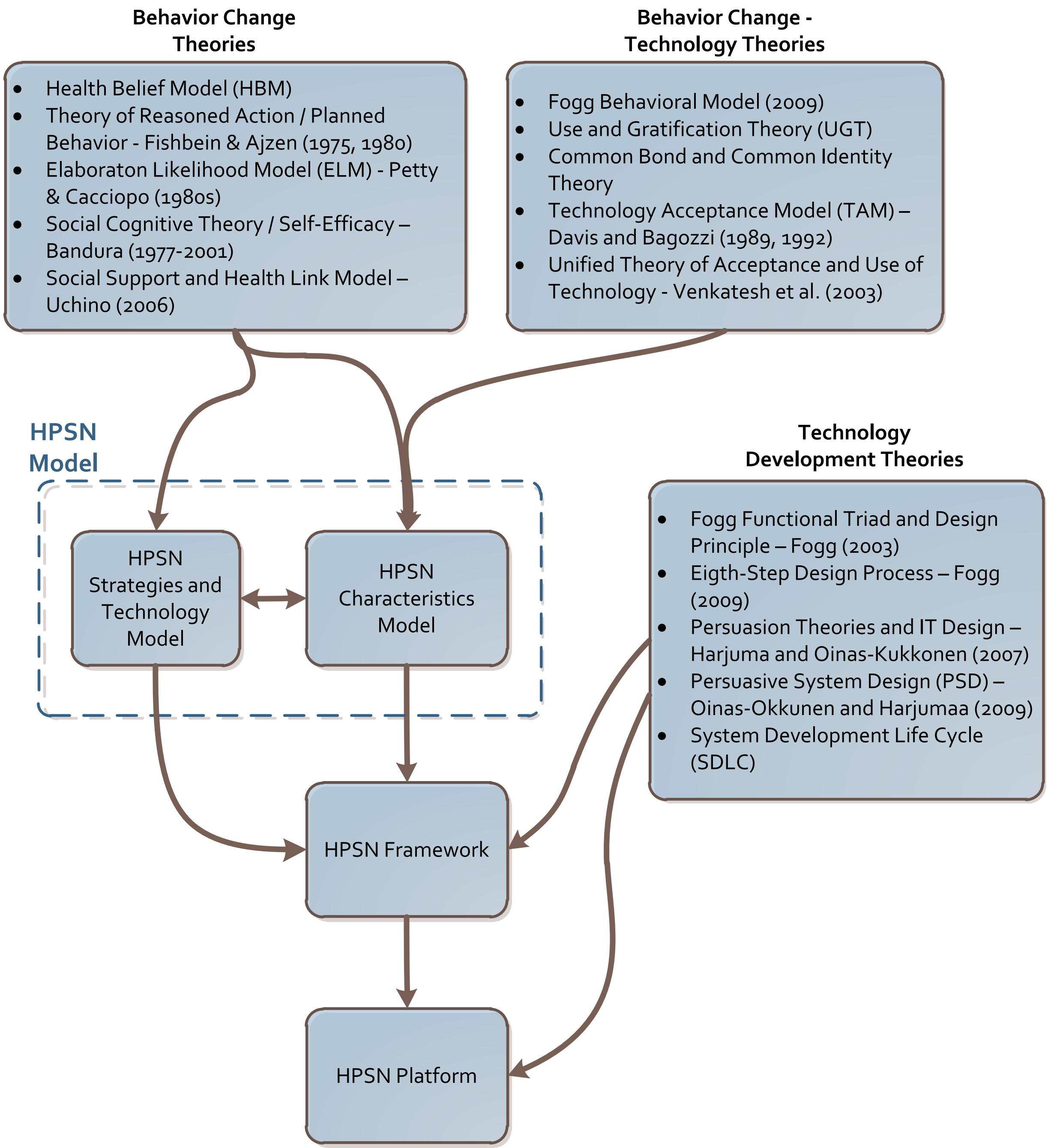

Figure 2-1. Correlation between the Fundamental Theories and the HPSN Components

In this chapter, an overview of each of the theories and models is provided; while the relevant aspects of these theories and models that are particularly relevant for the design of persuasive technology to encourage physical activity are discussed in more detail in Chapter 4 Chapter 5, and Chapter 6.

2.1 BEHAVIORAL CHANGE THEORIES

2.1.1 The Health Belief Model (HBM)

The Health Belief Model, originally developed by researchers at the U.S. Public Health Service in the 1950s, was first inspired by a study of why people sought X-ray examinations for tuberculosis; but in more recent years the model has been used to predict more general health behaviors. The underlying concept of the original HBM is that health behavior is determined by personal belief or perception about the disease and strategies available to decrease its occurrence. The following four perceptions serve as the main construct of the model: perceived severity, perceived susceptibility, perceived benefits, and perceived barriers. “Perceived severity” is defined as an individual's assessment of the seriousness of the condition and its potential consequences; “perceived susceptibility” is defined as an individual's assessment of their risk of getting the condition; “perceived benefits” refer to an individual's assessment of the positive consequences of adopting the new behavior; and “perceived barriers” speak to an individual's assessment of the influences that facilitate or discourage adoption of the promoted behavior.

More recently, two more elements have been added into estimations of what it actually takes to make someone to change a health behavior as sometimes wanting to change a health behavior is not enough. These two elements are cues to action and self-efficacy. “Cues to action” are events, people, or things that prompt a desire to make a behavior change. “Self-efficacy” is the belief in one’s own ability to do something (Bandura, 1977). Self-efficacy is added because people generally do not try to do something new unless they think they can do it.

2.1.2 Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB)

The Theory of Reasoned Action (TRA) was first proposed by Alzen (1975) and was later completed by Ajzen and Fishbein (1980). The key application of TRA is prediction of behavioral intention, spanning predictions of attitude, and predictions of behavior. The components of TRA are three general constructs: attitude (A), subjective norm (SN), and behavioral intention (BI). TRA suggests that a person's behavioral intention depends on the person's attitude about the behavior and subjective norms (BI = A + SN).

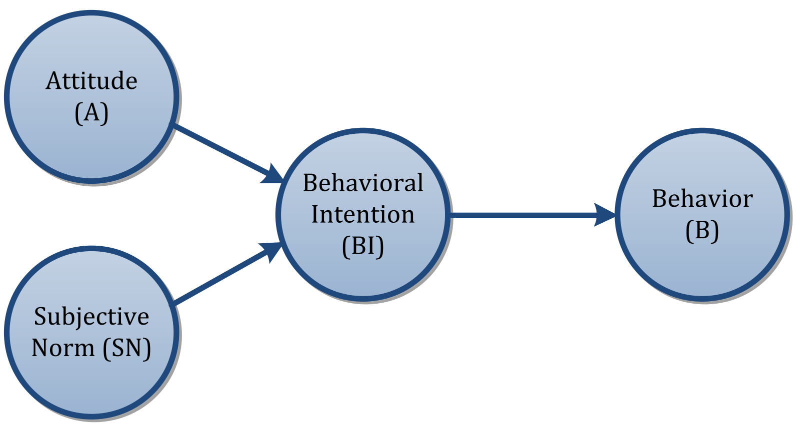

Figure 2-2. Theory of Reasoned Action

Behavioral Intention (BI) measures a person's relative strength of intention to perform a behavior (See Figure 2-2). Attitude consists of beliefs about the consequences of performing the behavior multiplied by his or her valuation of these consequences. Subjective Norm (SN) is seen as a combination of perceived expectations from relevant individuals or groups along with intentions to comply with these expectations (Ajzen, 1975).

To put the definition into simple terms: a person's volitional (voluntary) behavior is predicted by his/her attitude toward that behavior and how he/she thinks other people would view them if they performed the behavior. A person's attitude, combined with subjective norms, forms his/her behavioral intention. Fishbein and Ajzen (1980) say, though, that attitudes and norms are not weighted equally in predicting behavior.

> *"Indeed, depending on the individual and the situation, these factors might be very different effects on behavioral intention; thus a weight is associated with each of these factors in the predictive formula of the theory".*

In 1991, Azjen proposed an extension of the TRA by incorporating the notion of perceived control over behavior achievement as a determinant of behavioral intention or behavior (Figure 2-3). Adding this extension, the TRA then became the Theory of Planned Behavior (TPB). The TPB suggests that beliefs regarding the possession of requisite resources and opportunities increase the intention to perform the behavior. The more resources and opportunities individuals think they possess, the greater should be their perceived behavioral control over the behavior.

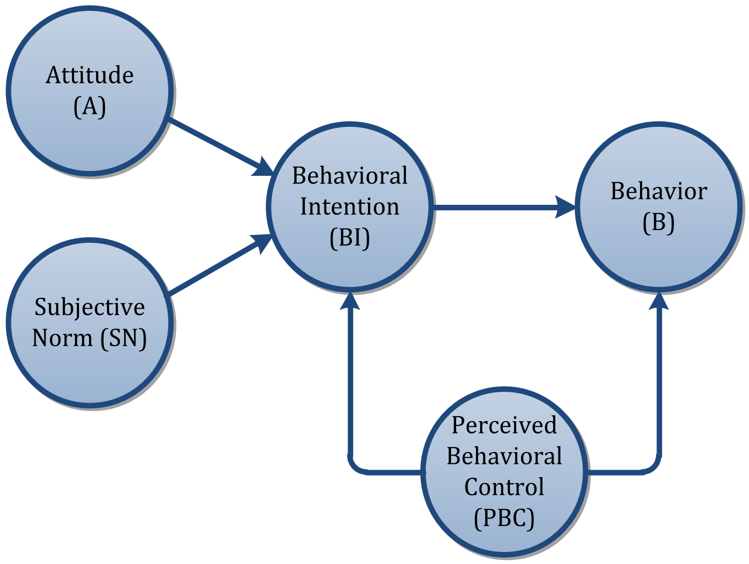

Figure 2-3. Theory of Planned Behavior

The TRA and TPB focus on theoretical constructs concerned with individual motivational factors as determinants of the likelihood of performing a specific behavior. TRA and TPB both assume that the best predictor of behavior is behavioral intention, which in turn is defined by attitude toward the behavior and social normative perceptions regarding it. The TRA and TPB, which focus on constructs of attitude, subjective norm, and perceived control, explain a large proportion of the variance in behavioral intention and predict a number of different behaviors, including health behavior.

2.1.3 The Elaboration Likelihood Model (ELM)

The Elaboration Likelihood Model (ELM) of persuasion was proposed by Petty and Cacioppo (1986). It describes two possible routes of persuasion or attitude change: the "central route," where a subject considers an idea logically, and the "peripheral route," in which the audience uses preexisting ideas and superficial qualities to be persuaded. The central route of persuasion entails careful evaluation of the merits of an advocated message. Thus, people who have a ‘need for cognition’ are more likely to take the ‘central route’ and will evaluate a message based solely upon its merits. Central route processes involve careful scrutiny of a persuasive communication (e.g., a speech, an advertisement, etc.) to determine the merits of the arguments. Under these conditions, a person's unique cognitive responses to the message determine the persuasive outcome (i.e., the direction and magnitude of attitude change). Therefore, if favorable thoughts are a result of the elaboration process, the message will most likely be accepted (i.e., an attitude congruent with the message's position will emerge), and if unfavorable thoughts are generated while considering the merits of presented arguments, the message will most likely be rejected (Petty & Cacioppo, 1986).

Conversely, the peripheral route of persuasion entails evaluation of an advocated message based not on its merits, but on tangential information surrounding the message. The peripheral route processes do not involve elaboration of the message through extensive cognitive processing of the merits of the actual argument presented. These processes often rely on environmental characteristics of the message, like the perceived credibility of the source, quality of the way in which it is presented, the attractiveness of the source, or the catchy slogan that contains the message. For example, a person evaluating an advocated message based solely on the attractiveness of the person giving the message is more likely to have taken the ‘peripheral route’ (Petty & Cacioppo, 1986).

2.1.4 The Transtheoritical Model (TTM)

The Transtheoritical Model was proposed first in 1977 by James Prochaska and colleagues (J. Prochaska & DiClemente, 1983, 2005; J. Prochaska & Norcross, 2010). In the Transtheoritical Model (TTM), behavioral change is a process involving progress through a series of stages. Those stages are:

1. *Precontemplation (Not Ready):* People are not intending to take action in the foreseeable future and can be unaware that their behavior is problematic.
2. *Contemplation (Getting Ready):* People are beginning to recognize that their behavior is problematic and start to look at the pros and cons of their continued actions.
3. *Preparation (Ready):* People are intending to take action in the immediate future and may begin taking small steps toward behavior change.
4. *Action:* People have made specific overt modifications to their problem behavior or have begun acquiring new healthy behaviors.
5. *Maintenance:* People have been able to sustain action for a while and are working to prevent relapse.
6. *Termination:* Individuals have zero temptation and they are sure they will not return to their old unhealthy habit as a way of coping (J. O. Prochaska & Velicer, 1997).

2.1.5 Social Cognitive Theory (SCT)

The Social cognitive theory (SCT) was proposed by Bandura (1986). It provides a framework for understanding, predicting, and changing human behavior by clearly identifying human behavior as an interaction of personal factors, behavior, and the environment. In the model (Figure 2-4), B represents behavior, P represents personal factors in the form of cognitive, affective, and biological events, and E represents the external environment. The interaction between the person and behavior involves the influences of a person’s thoughts and actions. The interaction between the person and the environment involves human beliefs and cognitive competencies that are developed and modified by social influences and structures within the environment. The third interaction, between the environment and behavior, involves a person’s behavior determining the aspects of their environment and in turn their behavior being modified by that environment.

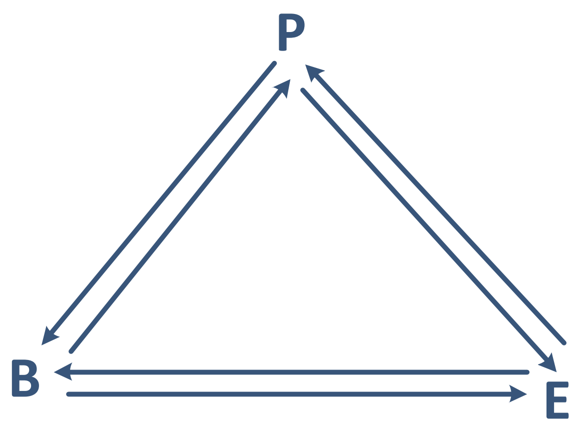

Figure 2-4. Social Cognitive Theory

Because SCT is based on understanding an individual’s reality construct, it is especially useful when applied to interventions aimed at personality development, behavior pathology, and health promotion. For example, SCT could be used to help a patient quit smoking in so far as a smoker may be more willing to learn from an ex-smoker who may share experiences that resonate with a patient’s unique personal history. Ideally, the patient’s affinity with the ex-smoker, when combined with a supportive environment, would help him or her to quit smoking.

2.1.6 Social Support and Physical Health Link (SSPHL)

Social relationships serve important functions in people's everyday lives. Epidemiological research indicates that supportive relationships may also significantly protect individuals from various causes of mortality. An important issue is how social support influences such long-term health outcomes. To explain this phenomena, Uchino (2006) proposed a broad model highlighting potential pathways linking social support to physical health (Figure 2-5).

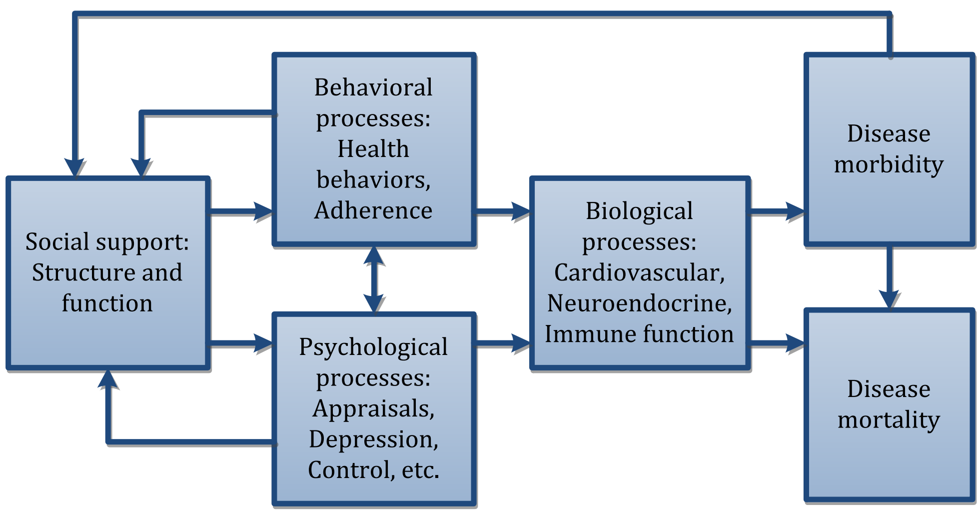

Figure 2-5. Uchino Social Support and Physical Health Link

Accordingly, structural and functional measures of support may ultimately influence morbidity and mortality through two distinct but not necessarily independent pathways. One pathway involves behavioral processes, including health behaviors and adherence to medical regimens. According to this view, social support is health-promoting because it facilitates healthier behaviors such as exercise, eating right, and not smoking as well as greater adherence to medical regimens. This can happen in a direct (e.g., health-related informational support) or indirect (e.g., life meaning) manner. In fact, health behaviors are one of the few variables that appear to explain at least part of the variance in the relationship between social support and mortality. The other major pathway involves psychological processes that are linked to appraisals, emotions or moods (e.g., depression), and feelings of control. Finally, these psychological and behavioral pathways may have a reciprocal influence on social support processes. For instance, psychological distress may influence perceptions of support and contribute to negative social interactions.

An additional important aspect of the model concerns the proposed links to and from disease morbidity. This makes salient two aspects of this broad model. First, the links with morbidity highlight the potential role of social support in the development of certain diseases. Second, the feedback loop between morbidity and social support highlights the unique challenges faced by individuals diagnosed with disease that can impact their social network. Close network members are often called upon as sources of support after the diagnosis of disease. Of central importance to this review is that the links between social support and disease are hypothesized to be mediated through relevant physiological processes, including changes in cardiovascular, neuroendocrine, and immune function. Finally, Uchino also highlighted that not all "supportive" relationships encourage healthier behaviors. Network ties can set a negative example and/or promote risky health behaviors as well.

Next, an overview of theories and models at the intersection between behavior change and technology development that influenced the development of the PersonA models, framework, and platform is provided.

2.2 BEHAVIORAL CHANGE – TECHNOLOGY THEORIES

2.2.1 Uses and Gratifications Theory (UGT)

Uses and Gratifications Theory is an approach to understanding why people actively seek out specific media outlets and content for gratification purposes. This theory discusses how users proactively search for media that will not only meet a given need but enhance knowledge, social interactions and diversion. The focus of the theory is on what people do with the media rather than the influence or impact of media on the individual. The theory was derived from Mass Communication Theory. In the early 1940s researchers began seeing patterns in the perspective of the uses and gratifications theory in radio listeners. Recently, a few studies were conducted to examine the Facebook and/or MySpace group user's gratifications. The results showed that there were at least three needs for using Facebook groups, "socializing, entertainment, and information" (Park, Kee, & Valenzuela, 2009; Quan-Haase & Young, 2010; Raacke & Bonds-Raacke, 2008).

1. *Socializing:* participants are interested in maintaining and/or creating new relationships with others to achieve a sense of peer and community support.
2. *Entertainment:* participants engage with the groups to amuse themselves.
3. *Information:* participants use the group to receive information about the group members or the group.

2.2.2 Common Bond and Common Identity (CBCI) Theory

The common identity theory is an approach to predicting the causes and consequences of people's attachment to the group as a whole; while the common bond theory is an approach to predicting the causes and consequences of people's attachments to individual group members (Yuqing, Kraut, & Kiesler, 2007). In Yuqing et al.'s work, they tried to identify the reasons people join online communities by reviewing 22 studies whose authors made an explicit distinction between identity and bond and who collected empirical evidence to examine either the distinction between the two or the convergent and divergent effects of this distinction. The summary of their results shows that the factors leading to a sense of common identity in online communities are as follows:

1. *Social categorization:* One can create group identity by defining a collection of people as members of the same social category.
2. *Interdependence:* Groups whose members are cooperatively interdependent tend to become committed to the group.
3. *Out-group presence/Intergroup Comparison:* People who define and categorize themselves as members of a group compare themselves with other groups.

While the factors leading to a sense of common bond in online community are described as follows:

1. *Social interaction:* A necessary cause of interpersonal bonds is interacting with others.
2. *Personal information:* Online community members are more likely to form relationships if they have opportunities to self-disclose and learn about each other.
3. *Interpersonal similarity:* People like and have a greater tendency to choose to work or interact with others similar to themselves. People are likely to become close to the extent that they perceive they are similar to each other in preferences, attitudes, and values.

2.2.3 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), first introduced in a thesis (Davis, 1989) is an adaptation of the Theory of Reasoned Action (TRA) to the field of information systems. The model suggests that when users are presented with a new technology, a number of factors influence their decision about how and when they will use it, notably:

1. *Perceived usefulness (PU):* the degree to which a person believes that using a particular system would enhance his or her job performance.
2. *Perceived ease-of-use (PEOU):* the degree to which a person believes that using a particular system would be free from effort (Davis, 1989).

As a note, these factors are related in the way that PU is seen as being directly impacted by PEOU (Figure 2-6). Later, researchers simplified TAM by removing the attitude construct found in the TRA from the original specification and proposed TAM-2 (Venkatesh, Morris, Davis, & Davis, 2003).

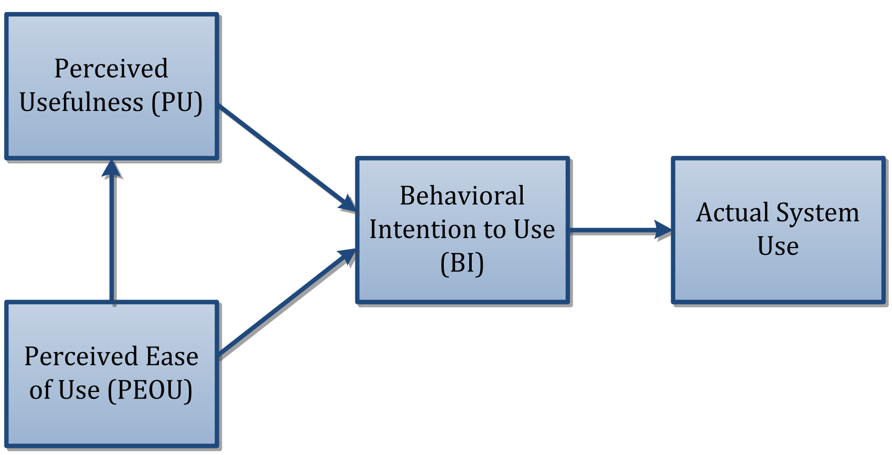

Figure 2-6. Technology Acceptance Model (TAM)

TRA and TAM, both of which have strong behavioral elements, assume that when someone forms an intention to act, that they will be free to act without limitation. In practice, constraints such as limited ability, time, environmental or organizational limits, and unconscious habits will limit the freedom to act.

2.2.4 The Unified Theory of Acceptance and Use of Technology (UTAUT)

Another extension of TAM is the Unified Theory of Acceptance and Use of Technology (UTAUT) proposed by Venkatesh, et al. (2003). It aims to explain user intentions to use an information system (IS) and subsequent usage behavior (Figure 2-7). The theory holds that four key constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) are direct determinants of usage intention and behavior. Gender, age, experience, and voluntariness of use are posited to mediate the impact of the four key constructs on usage intention and behavior. The theory was developed through a review and consolidation of the constructs of eight models that earlier research had employed to explain IS usage behavior (theory of reasoned action, technology acceptance model, and motivational model, theory of planned behavior, a combined theory of planned behavior/technology acceptance model, model of PC utilization, innovation diffusion theory, and social cognitive theory).

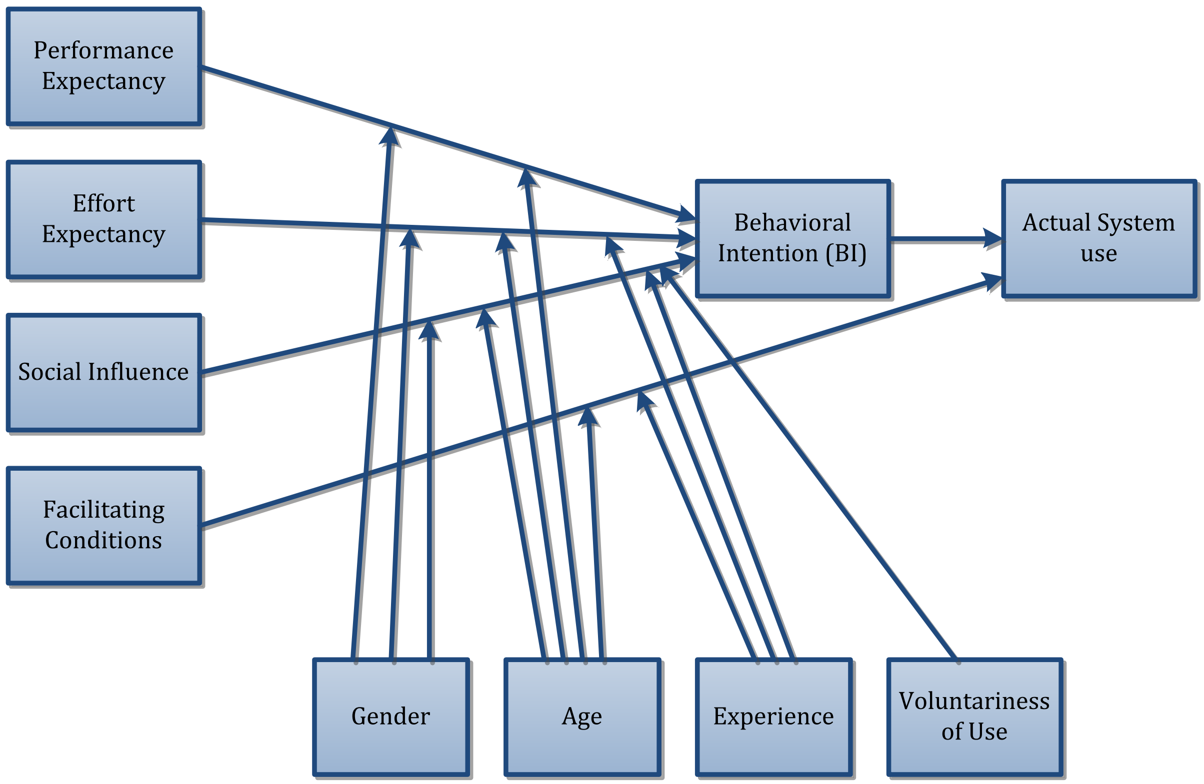

Figure 2-7. Unified Theory of Acceptance and Use of Technology (UTAUT)

2.2.5 Fogg Behavioral Model (FBM)

This work proposes a psychological model called the Fogg Behavior Model (FBM) designed specifically for persuasive technology. This model clearly identifies and defines three factors that control whether a behavior is performed. Those factors are motivation, ability, and trigger (BJ Fogg, 2009a). In brief, the model asserts that for a target behavior to happen, a person must have sufficient motivation, sufficient ability, and an effective trigger. All three factors must be present at the same instant for the behavior to occur. In most cases of persuasion, people are not on the extremes. Generally, people have at least a modest level of motivation and ability – and these levels can be manipulated. Effective persuasive technologies will boost either motivation or ability (usually by making something simpler, like 1-click action) or both. But that's not all: the behavior must be triggered. This third factor is often the missing piece in that without an appropriate trigger, the behavior will not occur even if both motivation and ability are high. In this case, people can potentially be triggered by getting feedback or information at the opportune moment through persuasive technology.

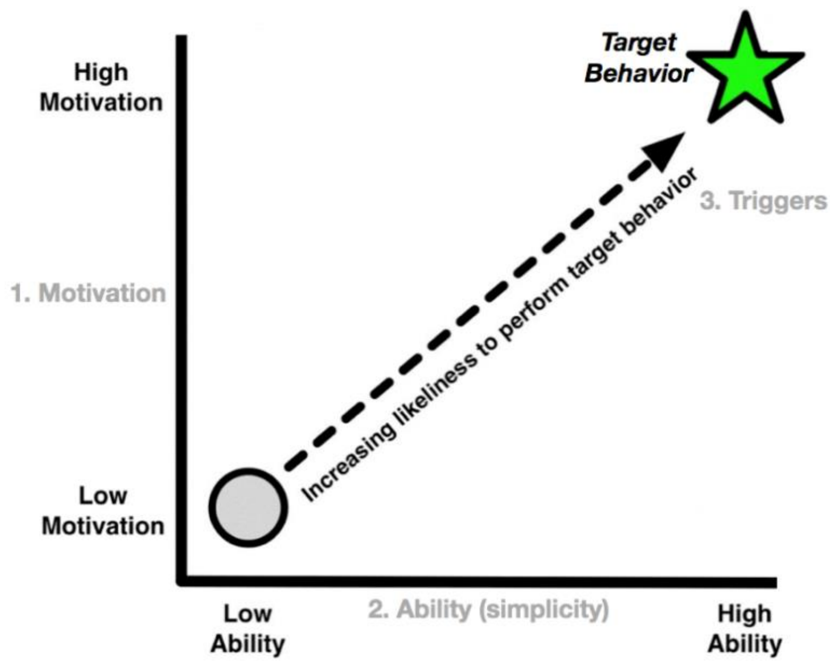

Figure 2-8. Fogg Behavior Model

Next, an overview of theories and models on technology development and evaluation that influenced the development of the PersonA models, framework, and platform is provided.

2.3 TECHNOLOGY DEVELOPMENT AND EVALUATION THEORIES

2.3.1 System Development Life-cycle (SDLC)

The systems development life cycle (SDLC) is a conceptual model used in project management that describes the stages involved in a system's development, from an initial feasibility study through maintenance of the completed system. Various SDLC methodologies have been developed to guide the processes involved, including the waterfall model (which was the original SDLC method); rapid application development (RAD); joint application development (JAD); the fountain model; the spiral model; build and fix; synchronize-and-stabilize; and Iterative and Incremental Development (IID). Some methods work better for specific types of projects, mostly depending of the characteristics of the system. A summary of various SDLC methodologies and its characteristics (pro and cons) has been published by the Center for Medicare and Medicaid Service (CMS) Office of Information Service (2008).

The waterfall model, as the first incarnation of the model, gives a fundamental description of distinguishable and sequential (may be iterative) steps in system development. The first formal description of the waterfall model is cited in an article by Winston W. Royce (1970), though Royce did not use the term "waterfall" in this article. It describes that system development is a sequential design process in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of *Conception, Initiation, Analysis, Design, Construction, Testing, Production (Implementation),* and *Maintenance* (Figure 2-9).

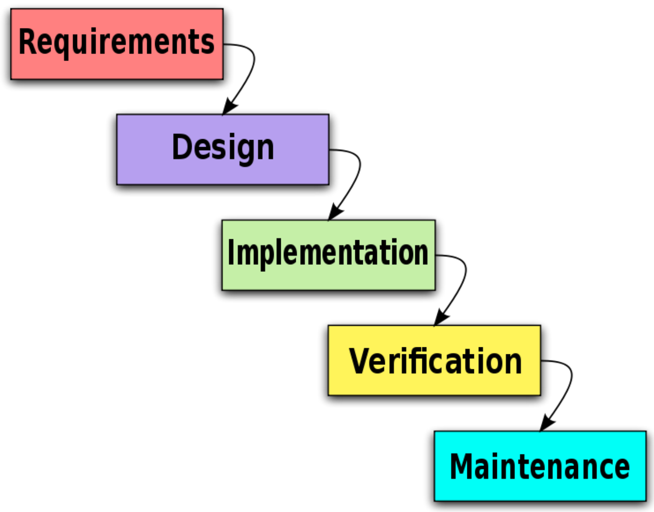

Figure 2-9. Software Engineering Waterfall Model

These steps are described in the following list:

1. *Requirements specification:* a phase to identify the problems a new system is supposed to solve, its operational capabilities, its desired performance characteristics, and the resource infrastructure needed to support system operation and maintenance.
2. *Design:* a phase to define the interconnection and resource interfaces between system subsystems, components, and modules in ways suitable for their detailed design and overall configuration management.
3. *Construction (or implementation or coding):* a phase to codify the preceding specifications into operational source code implementations and to validate their basic operation.
4. *Testing and Verification:* a phase to affirm and sustain the overall integrity of the software system architectural configuration through verifying the consistency and completeness of implemented modules, verifying the resource interfaces and interconnections against their specifications, and validating the performance of the system and subsystems against their requirements.
5. *Installation:* a phase to provide directions for installing the delivered software into the local computing environment, configuring operating systems parameters and user access

privileges, and running diagnostic test cases to ensure the viability of basic system operation.

6. *Maintenance:* a phase to sustain the useful operation of a system in its host/target environment by providing requested functional enhancements, repairs, performance improvements, and conversions.

The waterfall model maintains that one should move to the next phase only when its preceding phase is completed and perfected. However, there are various modified waterfall models, including Royce's final model in (Royce, 1970), that incorporate slight or major variations on this process. In this dissertation, the SDLC methodology used is Iterative and Incremental Development (IID), which includes the steps described in the waterfall methodology; however, the IID proposes that, instead of having steps which flow steadily downward, development processes grow a system feature by feature during self-contained cycles of analysis, design, development, and testing. In the end, it is expected that the IID will produce a stable, fully integrated and tested, partially complete system that incorporates all of the features of all previous iterations (Figure 2-10).

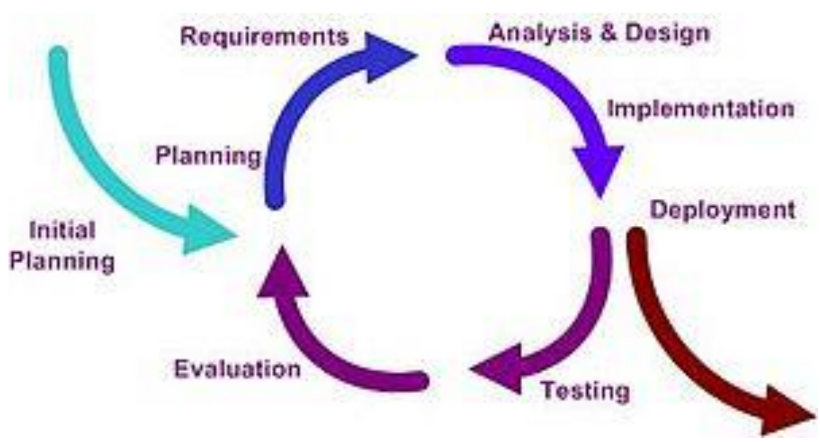

Figure 2-10. Iterative and Incremental Development (IID)

2.3.2 Fogg Functional Triad and Design Principle

The Fogg Functional Triad and Design Principle was proposed by BJ. Fogg (2003). The Functional Triad classifies three basic ways (functions) that people view or respond to technologies: as tools, media, or social actors – or as more than one at once (Figure 2-11).

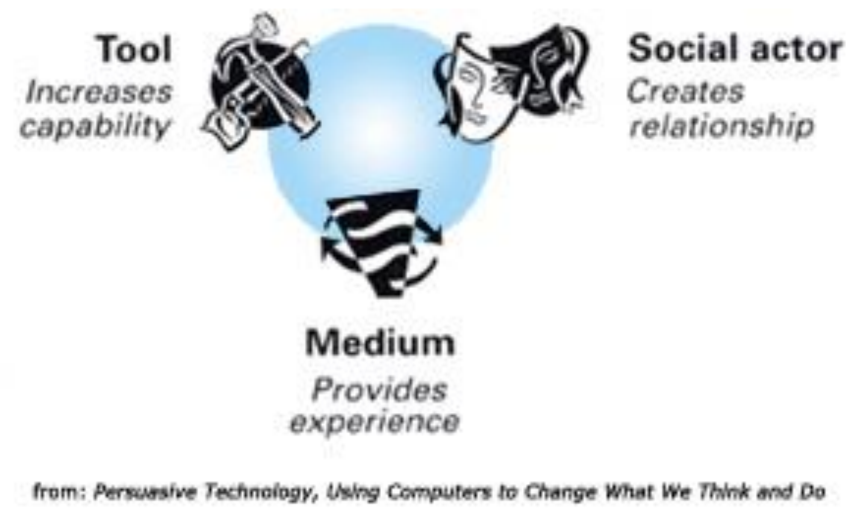

Figure 2-11. Fogg Functional Triad

In their role as tools, the goal of technologies is to make activities easier or more efficient (for example, calorie calculation, and physical activity measurement). Technologies serve as media when they are used to deliver or convey information. Technologies are social actors when users treat them as living entities or technologies are designed to behave such as living entities (for example, giving comments, providing feedback, and providing social support like living persons usually do). Fogg then defines role specific design principles that system developers should take into account. For example, when a developer designs a system which will act as a tool, the developer should implement the following design principles: *Reduction, Tunneling, Tailoring, Suggestion, Self-monitoring, Surveillance*, and *Conditioning*. In addition to design principles for each function, Fogg also defines more principles related to credibility, mobility, and connectivity of a system. The ultimate purpose of this design principle is to guide a system developer to design persuasive technology.

2.3.3 Fogg Eight-Step Design Process

This process was proposed by Fogg (2009b). Eight steps are suggested as best practices in the early stages of persuasive technology design. The eight-step process, drawn from demonstrated successes in industry practice, begins with defining the persuasion goal to match a target audience with an appropriate technology channel (Figure 2-12). Subsequent steps include: imitating successful examples of persuasive design, performing rapid trials, measuring behavioral outcomes, and building on small successes. Most of the steps are carried out in sequence. In some cases, two steps may be carried out in parallel; at other times, the design team may back up a step and re-think or re-try. The eight steps are not intended to be a rigid formula; instead, the steps serve as milestones to make the design process more effective.

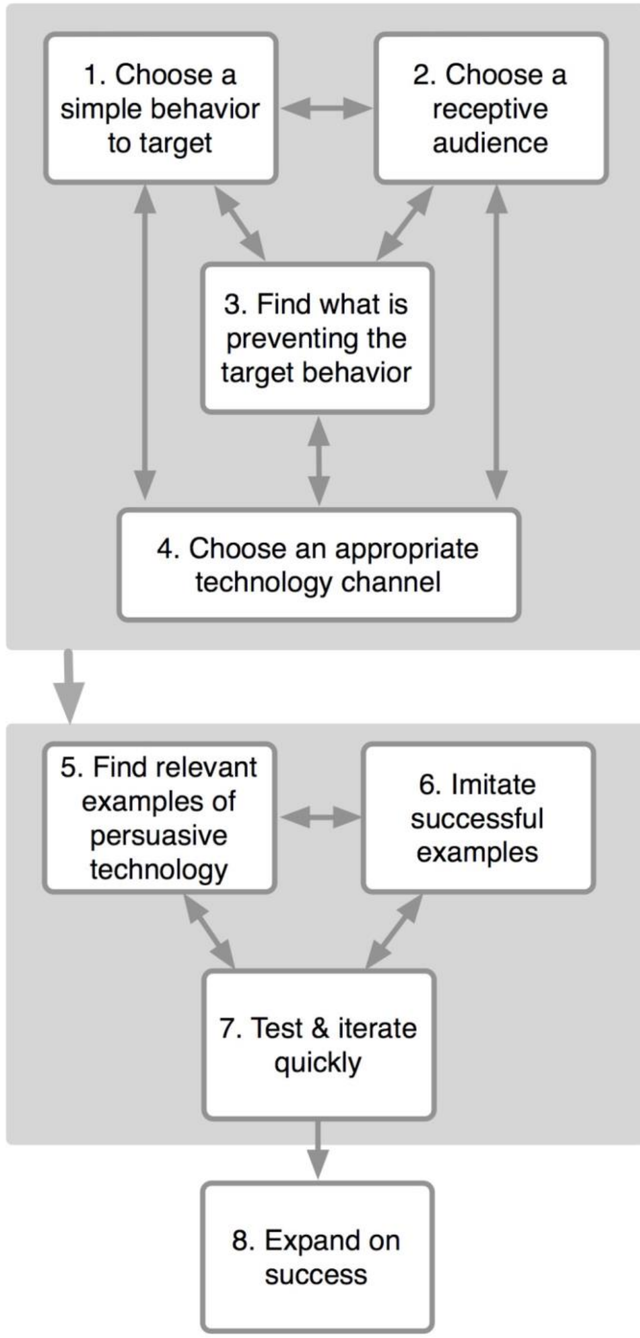

Figure 2-12. Fogg Eight-Step Design Process

The description of each step is highlighted below:

1. The first step in designing a successful persuasive technology is to select an appropriate behavior to target for change. The target behavior should be the smallest, simplest behavior that matters and be easy to measure.
2. The second step in the persuasive design process involves choosing the right audience for the intervention. The audience should be receptive to the targeted behavior change and be familiar with the technology channel.
3. The third step is to analyze and determine what is preventing the audience from performing the target behavior.
4. The fourth step is to choose the best channel for the technology intervention. Which channel is "best" usually depends on three factors: the target behavior, the audience, and what is preventing the audience from adopting the behavior—i.e., the first three steps in the design process. What this means is that in most cases, the design team cannot select an intervention channel– web, mobile phone, video game, or other— until the first three phases of the process have been completed.
5. The fifth step is to search for examples of successful persuasive technologies that are relevant to the intervention, as defined in the previous steps.
6. The sixth step is to imitate what's working in the successful examples gathered in Step 5.
7. The seventh step is to test various persuasive experiences quickly and repeatedly. A series of small, rapid tests will reveal more than one big test. These are not scientific experiments but quick trials that allow the design team to prototype the experience and see how people react. The team should assess the response, ideally by measuring behavior.
8. The eighth step is to expand or scale up the success.

2.3.4 Persuasion System Design (PSD)

The Persuasion System Design (PSD) was proposed by Oinas-Kukkonen and Harjumaa (2009). The PSD framework is the most comprehensive approach to developing persuasive systems. It brings a number of theories under one umbrella and advocates principles which facilitate the use of appropriate theories for developing persuasive systems. It categorizes persuasive system analysis into 3 main steps (see Figure 2-13) namely: (i) understanding key issues behind persuasive systems, (ii) analysis of the persuasive context, and (iii) design of system qualities.

The first group of steps facilitates the understanding of the key issue or problem and the two latter groups focus on the choices of strategies needed for the development. This framework explains that by understanding the persuasion context (the Intent, Event and Strategy), a designer can formulate the appropriate persuasive technique needed for an effective persuasive design. Then the PSD organizes the system qualities into four categories: primary task support, dialogue support, system credibility, and social support. These system qualities encompass the essential techniques applied in social influence and the persuasive tools proposed by Fogg (2003). It continues by carefully selecting techniques to stimulate, motivate and trigger the user towards the targeted goal. In addition, this framework provides 28 design requirements that can be used as both development and evaluation guidelines (mostly based on Fogg's principles of persuasive technology). Lastly, this framework is completed with software requirement and implementation examples.

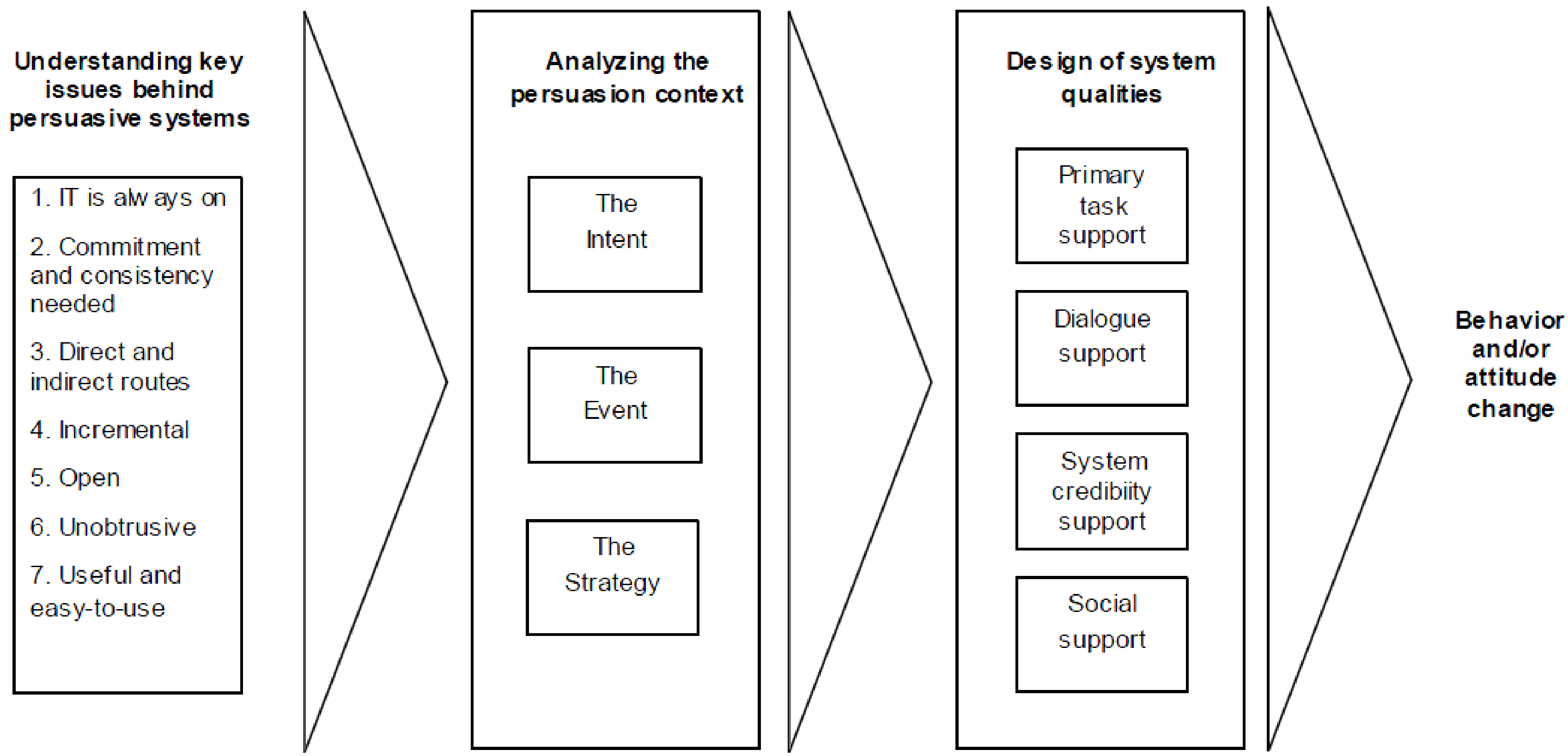

Figure 2-13. Persuasive System Analysis Steps

2.3.5 3D-RAB Model

Wiafe, Nakata, & Gulliver (2011) propose a model called 3D-RAB depicting a 3-dimensional relationship between attitude and behavior. They also demonstrate how it can be used in designing third-party persuasive applications in SNSs by considering the external factors affecting persuasive strategies. The 3D-RAB model can enable an application designer to categorize SNS users into groups during design based on cognitive dissonance states so as to present persuasive messages and techniques to support the transition towards a particular target state. They argue that a systematic strategy is needed to achieve the target behavior and propose the use of the 3D-RAB model. One of the major challenges in using the 3D-RAB model for designing persuasive technology is identifying which state the user is in. In this regard, SNSs have the ability to collect user feedback, which makes it possible for designers to collect information on, and possibly detect changes in, users, thus enabling the tailoring of persuasive approaches according to users' states.

2.4 USABILITY EVALUATION

2.4.1 Usability Factors

Usability testing is a technique used in user-centered interaction design to evaluate a product by testing it on users (Nielsen, 1993). It is important to realize that usability is not a single, onedimensional property of a user interface. Usability has multiple components and is traditionally associated with these five usability factors:

1. *Learnability*: the system should be easy to learn so that the user can rapidly start getting some work done with the system.
2. *Efficiency*: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
3. *Memorability*: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
4. *Errors*: The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
5. *Satisfaction*: The system should be pleasant to use, so that users are subjectively satisfied when using it, they like it.

2.4.2 Methods

To evaluate the five factors, the formative usability assessment usually utilizes the following three protocols: 1) think-aloud assessment; 2) post-study questionnaire; 3) and in-depth semi-structured interview.

First, think-aloud assessment (or think-aloud protocols, or TAP; also talk-aloud protocol) is a method used to gather data in usability testing in product design and development. This protocol was first introduced in the usability field by C. Lewis (1982) and then was explained more detailed in another work (Clayton Lewis & Rieman, 1993). The basic idea of this protocol is very simple as described by Lewis & Rieman in their article:

> *"You ask your users to perform a test task, but you also ask them to talk to you while they work on it. Ask them to tell you what they are thinking: what they are trying to do, questions that arise as they work, things they read. You can make a recording of their comments or you can just take notes. You'll do this in such a way that you can tell what they were doing and where their comments fit into the sequence."* (Clayton Lewis & Rieman, 1993)

Second, the post-study questionnaire was designed to evaluate the five usability factors quantitatively. A few researchers proposed "ready to use tool" of post-study questionnaires that all refers to the Nielsen work (Nielsen, 1993). The tools that are available for free and have been widely used are summarized in the Table 2. In this dissertation, the questionnaire used was a combination of and customized from the International Business Machine (IBM) Post-Study System Usability Questionnaire (PSSUQ) (J. R. Lewis, 1993a), Nielsen's Attribute of Usability (Nielsen, 1993), and the Technology Acceptance Model (TAM) (Davis, 1989). One additional factor was added to the questionnaire to address the use of more advanced technology used in this dissertation, especially smartphone technology (See Appendix C). That factor is navigation, which is very important in smartphone apps but was not included in the original PSSUQ, Nielsen's Attribute, or TAM as the smart phone technology hasn't yet existed when these were created.

Third, in-depth semi-structured interview was used to clarify and to elicit more elaborative explanation on any usability problems or improvements found in the first method (think-aloud) or second method (post-study questionnaire).

Table 2 Usability Questionnaires

Acronym	Name	Reference	Organization	# of Questions
QUIS	Questionnaire for User Interface Satisfaction	(Chin, Diehl, & Norman, 1988)	Univ. of Maryland	27 questions
PUEU*	Perceived Usefulness and Ease of Use (also known as Technology Acceptance Model - TAM).	(Davis, 1989)	IBM	12 questions
NAU*	Nielsen's Attributes of Usability	(Nielsen, 1993)	Bellcore	5 attributes
NHE	Nielsen's Heuristic Evaluation	(Nielsen, 1993)	Bellcore	10 heuristics
ASQ	After Scenario Questionnaire	(J. R. Lewis, 1995)	IBM	3 questions
PSQ	Printer-Scenario Questionnaire	(J. R. Lewis, 1995)	IBM	3 questions
PSSUQ*	Post-Study System Usability Questionnaire	(J. R. Lewis, 1995)	IBM	19 questions
CSUQ	Computer System Usability Questionnaire	(J. R. Lewis, 1995)	IBM	19 questions
PHUE	Practical Heuristics for Usability Evaluation	(Perlman, 1997)	OSU	13 heuristics
PUTQ	Purdue Usability Testing Questionnaire	(H. X. Lin, Yee-yin Choong, & Salvendy, 1997)	Purdue	100 questions
USE	USE Questionnaire	(Lund, 2001)	Sapient	30 questions
MPUQ	Mobile Phone Usability Questionnaire (MPUQ)	(Young Sam Ryu, 2005; Young Sam Ryu, Kari Babski-Reeves, Tonya L. Smith-Jackson, & Nussbaum, 2007; Young Sam Ryu & Smith-Jackson, 2006)	Virginia Polytechnic Institute and State University.	72 questions

NOTE: *Questionnaires used in this Dissertation

2.4.3 Data Analysis and Sample Size Consideration

Descriptive statistics were used to analyze the quantitative data obtained from the first and second protocols (think-aloud and questionnaire) in usability study. The quantitative data includes success rates of each task, error rates, and satisfaction questionnaire ratings. All statistical analyses were preceded by a detailed descriptive analysis of the data using standard descriptive summaries (e.g., means, standard deviation, percentiles, and ranges) and graphical techniques (e.g., histograms, scatter plots). On the other hand, content and thematic analysis was used to analyze the qualitative data obtained in the third method (in-depth semi-structured interview) in usability study. The qualitative data includes observations of pathways participants took, problems experienced, comments, and answers to open-ended questions.

Usability testing serves one of two purposes: formative evaluation or summative evaluation; the contrasting goals of these two forms of evaluations are reflected in the approach to usability testing as either problem detection or determining effectiveness. Problem detection studies usually use the following probabilistic Poisson model (later widely recognized as the Problem Discovery Rate Model) to determine the number of participants needed to uncover usability problems (J. R. Lewis, 1993b; Nielsen & Landauer, 1993; Virzi, 1992).

$$\text{Uncovered Problems} = N\,(1 - (1 - p)^n)$$

N: total number of usability problems in the design

p: proportion of usability problems discovered while testing a single user

n: number of subjects

This formula was first published in Nielsen and Landauer (1993), where they reported case studies supporting their claims for needing only small sample size were needed to conduct an accurate usability test. The work was extended from Virzi's (1992) which is recognized as the first work proposing small sample size in usability study. They and Lewis (1994) then identified important assumptions about the use of the formula for estimating problem discovery rates. The Problem Discovery Rate Model was then recently re-examined by Lewis (2001).

Given accurate probability estimation, this simple formula provides a fairly good prediction of the number of subjects needed to determine a certain proportion of usability problems. Using an average p value between .30 and .40 suggested by a number of studies (Nielsen & Landauer, 1993; Virzi, 1990, 1992) and, based on the cumulative binomial probability formula, led to a statement that testing only four or five users will uncover 80% of the usability problems. Indeed, this statement is being diminished after "five users number", a rule-of-thumb popularized in Nielsen's (2000) online article, which, after gaining support from Turner, C. W., Lewis, J. R., & Nielsen, J (2006), has continued to gain acceptance. This popular article uses p=0.31 which gives 85% of revealed problems when using five participants.

3.0 RELATED WORK

In addition to the fundamental theories and models overviewed in Chapter 2, the design of Health Persuasive Social Network (HPSN) was also informed by theories of and prior studies involving the implementation of self-management and social support in health intervention. In this chapter, a discussion of such theories and studies is presented, followed by an analysis of advances of technologies that are potentially relevant to the design of the HPSN. Specifically, this chapter starts with an analysis of self-management theories and their implementations in health intervention, which is then followed by a review of social support theories and their implementations in health intervention. This chapter ends with an analysis of current technologies and their potential usage as persuasive tools to promote a healthier life style.

3.1 SELF-MANAGEMENT AND HEALTH INTERVENTION

Self-management is discussed in this dissertation as one of the most important practical strategies in health behavior change. It has been widely implemented in research and treatment of chronic diseases. Self-management of illness refers to the daily activities that individuals undertake to keep the illness under control, minimize its impact on physical health status and functioning, and cope with the psychosocial squealed of the illness (Clark, Becker MH, Janz NK, Lorig K, & Rakowski W, 1991). Although these activities are typically undertaken in cooperation with a health care provider, self-management is more than just strict adherence to a prescribed behavioral regimen;

it involves a high level of control on the part of the patient, some autonomy with respect to adjusting the regimen as necessary, and deliberation in the form of decision-making and problem-solving.

Although some self-management tasks are illness specific (e.g., measuring blood glucose for diabetes, measuring blood pressure, sticking with diet, performing specific physical activity, inhaling asthma medicine), there are still commonly required masteries that cross illness categories to enable successful self-management of illness: 1) making *informed decisions about care* through education (Bodenheimer, Lorig, Holman, & Grumbach, 2002; Clark, et al., 1991; Ward et al., 2010); 2) performing *activities aimed at management of the condition* through self-monitoring and adjustment (Clark, et al., 1991; Mant, 2008; Ward, et al., 2010); and 3) applying *the skills necessary for maintaining adequate psychosocial functioning* (Clark, et al., 1991) through communication with health practitioner (Ward, et al., 2010) and support from family, peers, and society.

To achieve mastery in making informed decisions, self-management education is important. It aims to empower individuals living with chronic illness and disabilities to improve their quality of life and health outcomes by making them understand actions and behaviors that affect their health. Individuals taking part in such educational programs are taught problem-solving skills, in addition to the disease-specific information and technical skills taught in traditional patient education. These include, but are not limited to: understanding of relationships between their health status and behavioral and/or contextual factors (e.g. diet, physical activity, social influence, and so forth), understanding of symptoms and their causes, understanding of how to use self-monitoring equipment, and understanding of any subsequent actions or activities that need to be done. Mastering these problem-solving skills, in combination with knowledge of disease specific information, makes patients better able to identify health problems and take the actions necessary to manage their diseases and disabilities (Bodenheimer, et al., 2002).

This self-management education complements traditional patient education in supporting patients to have the best possible quality of life with their chronic condition. Unlike traditional patient education, which offers only one-way information and technical skills, self-management education teaches problem-solving skills (Bodenheimer, et al., 2002) and daily self-care decisions. Evidence from controlled clinical trials shows that 1) programs teaching self-management skills are more effective than information-only patient education in improving clinical outcomes; and 2) in some circumstances, it reduces costs (Bodenheimer, et al., 2002). If this evidence is true, self-management education for chronic illness may soon become an integral part of high-quality primary care.

The second mastery required to perform self-management is the high ability to perform subsequent actions needed to occur to lead to a clinical change. Those actions include self-monitoring, adjustment of treatment, and better adherence to treatment. Some examples of practical actions: managing acute episodes, taking medications, maintaining diet, performing physical activity, and quitting smoking. The last mastery required to perform good self-management is applying acquired skills to maintain psychosocial functions which include, but are not limited to, managing self-motivation, managing the psychological responses to illness, managing relationships with family, peers and society to promote support as well as managing communication with health practitioners to ensure adherence to the program.

The concept of self-management has been most widely incorporated in the treatment and research of diseases which rely heavily on personal behavior such as high blood-pressure, cardiovascular diseases, and diabetes mellitus (Agarwal & Lau, 2010; Ciemins & Sorli, 2010;

Kempf, Kruse, & Martin, 2010; Klein & Klein, 2010; McManus et al., 2010; Rao, Hou, Golnik, Flaherty, & Vu, 2010; Ward, et al., 2010). For example, in a randomized control trial study by McManus, et al. (2010), 527 participants were randomly assigned to self-management or control groups, and after 6 and 12 months, measurements of the effect of self-management on blood-pressure control were conducted. They found that self-management of hypertension, in combination with telemonitoring of blood pressure measurements, represents an important new addition to control of hypertension in primary care.

Another recent systematic-review by Cuching (2010) of 33 studies found that an eHealth intervention that incorporates behavioral methods (e.g., self-monitoring, goal setting, immediate feedback, contingency management) produces greater effects sizes on health behaviors and their associated outcomes than interventions that relied solely on education programs usually consisting of static one-way one-time interaction. One further study evaluated a tool called “self-monitoring of blood glucose” (SMBG) (Kempf, et al., 2010). It examined the impact of a tool to visualize immediate effects of food pattern and exercise on blood glucose levels and found that it is applicable to motivate individuals with type-2 diabetes to make lifestyle changes for the better. Specifically, 327 participants completed the program and significantly improved quality of diet and level of physical activity identified by an increase of > 2,300 steps/day. Participants significantly reduced weight, body mass index, waist circumference, blood glucose, blood pressure, and cholesterol, as well as showed increases in physical and mental health and reductions in depression measurements. Taken together, these studies demonstrate that self-management can play a significant role in dealing with chronic disease and disabilities.

Even though the aforementioned studies revealed a positive relationship between self-management and health outcomes, a few studies did find drawbacks to self-management implementation. For example, Tsai, et al. (2007) found that even though self-management is a critical skill for successful weight management, self-monitoring is labor-intensive and compliance to standard procedure is often difficult to achieve. In a diabetes study, Robinson, et al. (2010) found that self-monitoring of blood glucose (SMBG) is associated with improved glycemic control among patients with type 2 diabetes; however, the practice of daily self-monitoring was not optimal. Furthermore, Vallis (2009) mentions that there are a number of systematic barriers to self-management including individual-based, relationship-based, and environmental-based barriers. Han (2011) adds a consensus that although patients should take personal responsibility for their actions (self-management), patients need motivation to adhere to a regimen as well as education, reinforcement, individualized programs, monitoring, and other types of assistance from health care professionals to ensure successful treatment.

These weaknesses of self-management were actually recognized decades ago when it was informed by social cognitive theory in the 1980's (Bandura, 1986; Tobin, Reynolds, Holroyd, & Creer, 1986), which emphasizes that personal factors (especially beliefs and other cognitions) and environmental factors (both physical and social) interact to influence behavior (Gallant, 2003), including health behavior influencing health status. Therefore, as social cognitive theories illustrate, chronic illness self-management does not occur in a vacuum but rather in a context that includes formal health care providers (Gallant, 2003), social network members (e.g., family, peers, colleagues), and the physical environment (e.g., housing, air quality, and water quality).

Above, the fundamental concepts of self-management and how it is implemented in health intervention context are discussed. Next, an overview of the other health intervention strategy, social support, is provided.

3.2 SOCIAL SUPPORT AND HEALTH INTERVENTION

Social support is discussed in this research as, along with self-management, one of the most important practical strategies to be widely implemented in health behavior change. Social support refers to the resources that one receives from others, particularly people in one's immediate social networks with whom one has emotional bonds and/or social ties such as family, friends, schoolmates, coworkers, and even professional helpers such as health practitioners or social workers within one's community (Edlin & Golanty, 2010). Social support has been shown to directly and indirectly affect health (B. Uchino, 2006). Uchino argued that the direct effects on health are likely achieved through the psychological processes that are related to feelings and mood. For example, a positive social relationship may make a person feel less stressed, which could directly impact physiological functioning. Social support indirectly influences health because people who are socially active tend to engage in behaviors that lead to a healthier life style and prevent disease such as eating and exercise correctly (B. Uchino, 2006).

Apart from whether social support influences health directly or indirectly, Campbell, Phaneuf, & Deane (2004) identified three mechanisms by which social support influences health outcomes: 1) social support protects or enhances health directly by enhancing coping skills and indirectly by mediating the stress response, 2) being able to compare one's own experience of illness or disability with similar others through social interactions may normalize the experience, provide positive role modeling, encourage health promoting behaviors and enhance self-esteem, 3) social support enhances the opportunity to help others which leads to better self-esteem. In addition, Campbell, et al. (2004) and Edlin (2010) identified four important types of social support in health intervention and rehabilitation:

1. *Emotional support:* This is based on empathetic communication between patients and their support network intended to: enhance self-confidence and self-esteem, reduce negative feelings, and improve relationship. It includes, but is not limited to, reassurance, acceptance, love, trust, and intimacy.
2. *Informational support:* This can increase knowledge as well as increase understanding and coping skills, thus enhancing one's sense of self-control. It includes, but is not limited to, specific information and knowledge of the symptoms, how to deal with those symptoms, and identifying the causes.
3. *Appraisal support:* This can help people with chronic illness or disabilities to perform daily self-decision-making.
4. *Inclusion support:* This can help people with chronic disease and special needs to feel they are part of a group. It includes, but is not limited to, encouraging feelings of belonging to the community or a group and access to social contacts and group activities.

Many researchers have been trying to examine the premise that social support is associated with health-problem behavior; the majority of the findings demonstrate that social support does play an important role in the promotion and the spread of healthier behavior (Campbell, et al., 2004; Christakis & Fowler, 2007, 2008; Colella & King, 2004; Duncan, Duncan, & Strycker, 2005; Edlin & Golanty, 2010; Hanson, Sven-Olof Isacsson, Lars Janzon, & Lindell, 1989; Kimm et al., 2005; Leahey, LaRose, Fava, & Wing, 2010; Neumark-Sztainer, Story, Hannan, Tharp, & Rex, 2003; Postma, Karr, & Kieckhefer, 2009; K. Smith & Nicholas, 2008; Tilkeridis, O'Connor, Pignalosa, Bramwell, & Jefford, 2005; Voorhees et al., 2005). For example, in a large sample of adults (12,067) with 32 years of data collection, Christakis (2007) found that a person's chance of becoming obese increases 57% if a friend becomes obese; increases 40% if a sibling becomes obese; and 37% if a spouse becomes obese. The findings of studies of smoking cessation programs are similar. Using the same dataset used to analyze obesity, Christakis (2008) examined the spread of smoking in social networks and found that having more social contacts who smoke is associated with greater incidence of smoking. Among the 12,067 adults, the researchers showed that a person's chance of smoking decreases 67% if a spouse participates in cessation; decreases 25% if a sibling participates in cessation; and decreases 36% if a friend participates in cessation.

Similarly, the pattern holds for alcohol consumption problems. Using the same dataset as the two aforementioned studies, one study indicates that persons are 50% more likely to drink heavily if a person they are directly connected to drinks heavily; and individuals are 29% more likely to abstain from alcohol consumption if someone they are directly connected to abstains. (Rosenquist, Murabito, Fowler, & Christakis, 2010).

Another study called The Trial of Activity for Adolescent Girls (TAAG), involving large multi-centers in the U.S. tried to examine an association between physical activity and social networks. This research was originally devoted to finding ways to reduce the decline of physical activity in adolescent girls (Voorhees, et al., 2005), but an important finding was also revealed: verbal persuasion, modeling, and social support from family and peers help young people/teens to overcome barriers and become more physically active (Voorhees, et al., 2005; Vu, Murrie, Gonzalez, & Jobe, 2006). This similar finding is also supported in many other studies (Consolvo, Katherine Everitt, Ian Smith, & Landay, 2006; Kimm, et al., 2005; Neumark-Sztainer, et al., 2003; Toscos, Anne Faber, Kay Connelly, & Upoma, 2008). These studies have shown that the spread of health-behavior problems and the motivation to overcome the problems are both closely associated with social ties, social influence, and social support.

Researchers have conducted extensive studies to examine the association between social influence and chronic disease as well, with a special focus on high blood pressure and cardiovascular concerns. This is because the care for these diseases relies heavily on self-management and mostly on social support. Two systematic-review studies (Gallant, 2003; van Dam et al., 2005) showed that social support positively influences self-care and care outcomes of chronic illnesses, especially for diabetes; however, those results are heterogenic and hardly comparable in the review processes. A study by Brownstein, et al., (2007) where 14 studies were identified, including eight Randomized Control Trials (RCTs), tried to examine the association between social support from health workers and hypertension care's outcomes. It found that social support from health workers improved the patient's self-management behavior, including appointment keeping and adherence to the medications

In cancer treatment, the benefits of support services for patient are well established (Campbell, et al., 2004; Macvean, White, & Sanson-Fisher, 2008; Tilkeridis, et al., 2005). In addition to these studies, two other meta-analysis studies revealed that cancer patients who receive social support experience lower rates of anxiety, depression, nausea and pain, and have significantly greater knowledge regarding their disease and its treatment (Devine & Westlake, 1995; Sheard & Maguire, 1999). These findings indicate that social ties have a strong influence on chronic illness, including cancer care outcomes.

Above, two strategies (self-management and social support) in health intervention and rehabilitation are discussed. Next, an overview and simple analysis of persuasive technology and its implementation in health intervention that informed the development of PersonA models, framework, and platform is provided.

3.3 PERSUASIVE TECHNOLOGY AND HEALTH INTERVENTION

Persuasive technology has been implemented in many areas including education, transportation, and healthcare. Even though the term "persuasive technology" itself is not well known in health-related areas, it is a term that has been in use for a long time. Three examples of persuasive technology that have been around for a long time in health intervention and promotion are pedometers, blood pressure raters, and heart rate monitors. These tools may directly or indirectly persuade the users to have healthier behavior when the reading results are not as expected. Very recently launched game technologies which can recognize movement through haptic technologies[13] (such as Kinect[14] and Wii[15]) are also persuasive technologies and are widely available, relatively inexpensive, and used by many people today. These game technologies may naturally motivate users to have intermediate-intensity physical activities by having more active movement result in a higher score.

There are a few recent studies that examine the research question of whether this advanced technology could support and motivate people with chronic disease and/or disability. These studies

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[13] Haptic technology, or haptic, is a tactile feedback technology that takes advantage of the sense of touch by applying forces, vibrations, or motions to the user. This mechanical stimulation is mainly used to control virtual objects and to enhance the remote control of machines and devices. This technology is widely implemented in game technology, including physical activity-based games.

[14] Kinect is a motion sensing input device implementing haptic technology released by Microsoft for the Xbox 360 video game console and Windows PCs.

[15] The Wii is a home video game console implementing haptic technology released by Nintendo.

look at *UbiFit Garden* (Consolvo, et al., 2006), *Fish'n'Steps* (J. J. Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux, & Strub, 2006), *Jogging Over a Distance* (Mueller & Thorogood, 2007), *Shakra* (Maitland et al., 2006; Toscos, et al., 2008). Most of these studies found that persuasive technology is important for users to manage their condition. For example, Consolvo (2006) concluded that persuasiveness strategies such as giving the user credit for activities and providing personal awareness of activity level, are important for such a technology. *Fish'n'Steps* (J. J. Lin, et al., 2006), *Jogging Over a Distance* (Mueller & Thorogood, 2007), *Shakra* (Maitland, et al., 2006; Toscos, et al., 2008) used social influence as a physical activity motivator in their study of adults and found it important. In summary, it is possible that the advancement of information technology may improve adherence to recommended self-management practices by remotely transmitting feedback, intervention, or informed-choice to motivate patients as well as utilizing social networks for peer support. In addition, the use of integrated mobile telecommunications technology in chronic disease management may empower patients in their own self-care and ease the burden on health-care providers. The aforementioned studies demonstrate that persuasive technology can indeed be a very important tool in health-behavior interventions.

Now that the fundamental concepts and the importance of persuasive technology implementation in health intervention —including its case studies— have been presented, we move on to an analysis of three advanced technologies that have the potential to be combined as a persuasive technology to promote more active PA.

3.4 POTENTIAL TECHNOLOGIES FOR PERSUASIVE TECHNOLOGY IN HEALTH INTERVENTION

3.4.1 Sensing technology / BSN (Body Sensor Network)

The benefits of self-monitoring in chronic disease and disabilities management have been amply demonstrated. However, self-measuring regimes have to take into account the accuracy of the monitoring devices, the run-in period required to ensure patients are safe and effective at self-measuring, the quality assurance of the monitoring device and the frequency with which patients are required to self-measure (Ward, et al., 2010). Moreover, self-monitoring using manual data input such as paper-pencil or even manual electronic input can be cumbersome, subject to unreliable data because of human limitations, and subject to biases associated with retrospective recall. As a result, low adherence in manual self-monitoring commonly occurs (Guerci et al., 2003; Moss, Prue., Lomax., & Martin, 1982).

Sensing technologies offer an alternative to traditional self-measuring tools by providing reliable, comfortable, and automatic data collection. Right now, these kinds of technologies are anticipated to grow to more than 400 million devices by 2014 (MobileHealthNews, 2010) and are currently available with multi-functions, small size, and low price depending on user needs and preferences. Examples of these technologies are: pedometers/step counters, digital thermometers, heart rate monitors, and energy expenditure monitors. Many of the current generation of these devices use wireless and Bluetooth technology to transmit the information to personal computers or smartphones and then over the internet to various online programs which help in monitoring health status.

In relation to PA monitoring tools, commercial systems implementing this sensor technology include the Nike+ system[16], BodyMedia system[17], and heart rate monitors. Currently, perhaps the most common and widely used commercial device that detects physical activity throughout the day is the pedometer—an on-body sensing device that detects the number of "steps" the user takes. Its advantages to increase PA level are widely known. For example, results from one meta-analysis suggest that pedometer use is associated with significant increases in physical activity—a magnitude of about 2,000 steps or about 1 mile of walking—per day (Bravata et al., 2007).

A common problem when designing extension systems (e.g., a system providing feedback) needed in health behavior change programs based on commercial equipment —such as the aforementioned systems and traditional pedometer— is their closed nature, which usually prevents the capture of activity information. As a consequence, users must enter the data manually to the extension system through self-report or daily log. However, prior research indicates that non-manual (automatic) data collection not only can provide more accurate and detailed estimates of PA information (in some circumstances and given additional input parameters) but also can reduce the burden on users or physical educators/researchers/physician (Jonathan, Choudhury, & Borriello, 2006; Raustorp et al., 2011; Shuger et al., 2011; Westerterp, 2009). This problem has been recognized and has led the development of open architecture of PA monitoring devices.

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[16] http://nikeplus.nike.com/plus/

[17] http://www.bodymedia.com/

One of the pioneering works is a project aimed at developing a technology that can detect a wide range of physical activities such as walking, running, and resistance training (Bao & Intille, 2004). The users of this system must wear multiple accelerometers simultaneously on different parts of the body (e.g., wrist, ankle, thigh, elbow, and hip). While this approach is known for yielding strong accuracy rates, it is not practical when considering all-day, everyday use. Another approach uses multiple types of sensors (e.g., accelerometer, barometer, etc.) worn at a single location (e.g., hip, shoulder, or wrist) (Jonathan, et al., 2006). Such multi-sensor devices are more practical for daily use, while still being capable of detecting a range of activities.

A different approach is to infer physical activity from devices the user already carries/wears, such as Sohn et al.'s software for GSM smart phones that uses the rate of change in cell tower observations to approximate the user's daily step count (Sohn et al., 2006). One software called Shakra also uses the mobile phone's travels to infer total "active" minutes per day and states of being stationary, walking, and driving (Maitland, et al., 2006). Recently, with the advances in smartphones enabling them to provide not only communication channels but to also include sensing features, developers have been trying to develop a smartphone-based pedometer and deploy it in PA promotion. For example, Nicholas D. Lane et al., (2011) developed and technically evaluated a smartphone-based PA monitoring and encouragement system called BeWell. BeWell is a personal health application for smartphones designed specifically to help people manage their overall wellbeing by continuously monitoring multiple dimensions of behavior such as PA and sleep and incorporating user feedback mechanisms that are able to increase user awareness of how different aspects of lifestyle are impacting the personal wellbeing of the user.

3.4.2 Social Networking Systems

A social network system is a site designed to allow users to create and publish content themselves and decide which other users that they can connect to. Those contents commonly include profile information, notes, status, or event comments on others' content. The information may be on any subject and may be for consumption by (potential) family, friends, mates, employers, and/or employees, or remain private, only for themselves. The networking is possible either by linking one user to others, enabling a one-to-one connection/relationship, or by being a member or fan of a group or organization of people with shared interests. Examples of popular social networking sites include Facebook[18], Twitter[19], and Google+[20].

Social networking is entering the health care arena at the same time new information technologies are making it easier than ever for Internet users to find timely, relevant, and personalized health information. Internet users have been able to find this information through email discussion groups and chat rooms, which enable them to share experiences and information about treatment, and to build a personal network of friends or support groups. Social network systems have advanced networking and sharing by developing better interfaces, more flexible friend management, more sophisticated data sharing, more interactive communication methods, and by becoming more case-study oriented. The social network systems that have been

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[18] www.facebook.com

[19] www.twitter.com

[20] https://plus.google.com

successfully running in health care include PatientsLikeMe[21], SecondLife[22], DailyStrength[23], and Healia[24]. At DailyStrength, for example, patients and caregivers dealing with hundreds of issues, including asthma, celiac disease and depression, can join a support community, start a wellness journal, share advice and recommend doctors, link to news stories and Web sites with disease information, and even send other members a virtual hug.

Researchers have explored many aspects of how social networking services are used in health intervention. Some recent studies have investigated situations where both real and online social network systems are used to leverage social influence outside of health practitioner recommendations and family influence and found positive results (Albaina, Visser, van der Mast, & Vastenburg, 2009; Bravata, et al., 2007; Consolvo, et al., 2006; J. J. Lin, et al., 2006; Maitland, et al., 2006; Medynskiy & Mynatt, 2010; Mueller & Thorogood, 2007; Toscos, et al., 2008). In addition, a study by Duncan, et al. (2005) found that social support from friends (peers) when compared with that from parents or siblings, had the strongest relationship with physical activity levels. Those studies used either a computer or cell phone combined with sensing technologies, such as a pedometer, to encourage people to increase their physical activity. Because social network technology connects people having similar experiences dealing with relevant health issues, their use often leads to better self-management practices through self-comparison

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[21]http://www.patientslikeme.com/

[22]http://secondlife.com/

[23]http://www.dailystrength.org/

[24]http://www.healia.com/

mechanisms and leads to social influence through social comparison and sharing mechanisms. Moreover, they can have that access without any time-geographical limitations and psychological barriers (by being anonymous), which are both very important issues for many people with chronic disease or disabilities.

One key characteristic strength of using SNSs as persuasive platform is mass participation, which facilitates promotion of persuasive activities. This is because they serve as a platform for discussions and sharing of ideas, within a larger community, across geographical boundaries. What differentiates them from many other persuasive technology platforms is that they are inherently collective and thus make use of group dynamics; a powerful factor in the context of persuasion (Khaled, Barr, Noble, & Biddle, 2006). A study conducted by Fogg explained the collective factor of SNSs in the context of persuasion by proposing a concept of Mass Interpersonal Persuasion (MIP) (B. J. Fogg, 2008). MIP proposes six components supporting SNSs as being a perfect platform for persuasive activities, namely, they provide: a persuasive experience, an automated structure, social distribution, rapid cycling, a huge social graph and a measured impact. Persuasive experience is a form of experience that is created to change attitudes, behaviors, or both. The creator of the experience aims at making an impact on people's lives. Persuasive experience can then be structured as a digital technology, allowing the software to present the experience repeatedly, which is known as automated structure. Automated structure enables easy sharing of experiences with other users within a social network. Social distribution enhances the ability for the persuasive experience to be shared between peers on the network. In rapid cycling, persuasive experiences are distributed quickly within the network. Fogg argued that the experience is therefore capable of reaching millions of people who are connected through social ties, thereby creating a huge social graph. Also the impact of the experience is readily observable by both users and designers as the system provides information on connected peers. He added that though these components existed before, some SNSs have bundled them together and made them more useful for third party persuasive applications (B. J. Fogg, 2008).

3.4.3 Smartphone

Currently, the smart phone platform has become one of the most important platforms and a key driver of the advancement of health care delivery. This has occurred for two main reasons first, their use reaches a significant number of people. They represent 12 percent of total global handsets in use in 2012 (Cisco, 2012) and in the US, their use has steadily increased with 35-36.4% of the population currently using smart phones, compared to 16.4% two years ago (Cisco, 2012; CTIA The Wireless Association, 2010; Nielsen Consulting, 2011; Tomi Ahonen Consulting, 2011; US Census Bureau, 2010); second, they have unique characteristics that distinguish them from other technology, that is, they are: carried on the person, always turned on, personal, portable, sensible, connected, and their functionality is continually improving.

To date, however, the public conception of smart phones has focused on their use as a tool for communication and maintaining social identity. However, the ubiquity of smart phones, combined with their increasingly larger computing power and screen size, as well as increasingly developing integration capabilities with other technologies and network communication capabilities, present an obvious opportunity for almost any aspect of health-related applications. First, the always-carried and always-on nature of smart phones and availability of connection channels anywhere means that users can perform self-management in situ at their convenience anytime, anywhere. This means that using smart phones in health care delivery can better help users change their behavior, leading to a better health condition by allowing them to make informed decisions through immediate feedback of their behavior. Second, the smart phones also allow users to perform self-measurement, self-goal setting, and self-control based on feedback generated from smart phones. Third, the increasing computing power and better internet connection of smart phones allows for more sophisticated assessment and intervention to be remotely processed in a server or locally in a smartphone, depending on the need. These advanced functions and capabilities, combined with more convenient interaction features (e.g., bigger screen size, touch screen) may lead and persuade people to better adherence to health programs.

The rapid advancement in mobile communication technologies offers innumerable opportunities for the development of software and hardware applications to integrate smart phone technology with other technologies (e.g., sensing technology, web technology, etc.) and to develop health applications. Therefore, some health programs (e.g., remote monitoring of such chronic diseases) that were previously impossible can now be done effectively and efficiently. Researchers and system developers have been trying to develop several types of mobile health applications that can be classified into two categories: monitoring and communication-support applications. Monitoring applications include cardiac, glucose, vital signs, and physical activity monitoring systems. Communication & support applications include applications for appointment reminders, health education and promotion, compliance, behavior modification, and remote consultation. One study which explored the benefits of using these advancements in health care delivery focused on mobile phone implementation in diabetes and hypertension management, where the following services were accomplished remotely: (1) collecting blood pressure readings from the patient through a mobile phone; (2) providing this data to doctors through a Web interface; and (3) enabling doctors to manage the chronic condition by providing feedback to the patients remotely (Agarwal & Lau, 2010).

Even though the implementation of smart phones in health care delivery is very promising in researchers' view, still patient willingness to use the system is the primary key to its success. Proudfoot et al. (2010) found that the reasons given for interest in using a smart phone program are: convenience, counteracting isolation, and helping to identify triggers to mood states. On the other hand, reasons given for lack of interest included not liking to use a mobile phone or technology, concerns that it would be too intrusive or that privacy would be lacking, and not seeing the need. Design features considered to be of prime importance by participants were: enhanced privacy and security functions (including use of user name and password), ease of use, the provision of reminders, and the availability of clear feedback.

Above, a review of the three technologies (sensing technology, SNSs, and smartphone), with regards to their characteristics and potential to be combined and used as persuasive technology in promoting healthier behavior is provided. Given the aforementioned user needs and technology characteristics, the potential for using these technologies as persuasive technology should be explored. Next, a model that translates the health intervention strategies (Self-management and Social Support) to technological characteristics is provided. This translation is also informed by the persuasive technology concept along with the aforementioned related fundamental theories (HBM, TRA, TPB, ELM, TTM, SCT, SSPHL, UGT, CBCI, TAM, and UTAUT). The model is then extended to consider the position of the three technologies in the health intervention context and the technological characteristics model.

4.0 MODEL OF THE HEALTH PERSUASIVE SOCIAL NETWORK

With advances in persuasive technology and its wide application in health behavior change, a few researchers at the intersection of health behavior change and software engineering have been trying to apply behavior change theories and models as well as persuasion theories to software development practices and proposing design principles and development-evaluation frameworks. Those principles and frameworks include the Functional Triad and Design Principle (BJ. Fogg, 2003), Persuasion Theories and IT Design (Marja & Oinas-Kukkonen, 2007), the Eight-Step Design Process (BJ Fogg, 2009b), Persuasive System Design (Oinas-Kukkonen Harri & Harjumaa, 2009), the Framework for Health Behavior Change through Social Media (Kamal, et al., 2010), and Five Strategies for Supporting Healthy Behavior Change (Medynskiy, et al., 2011). All the aforementioned frameworks and principles provide a useful means for understanding ‘persuasive technology’, but unfortunately these seem to be too general for designing and evaluating ‘health persuasive technology’. Only two include the health behavior change context to some extent (the Framework for Health Behavior Model and Five Strategies for Supporting Healthy Behavior Change). None provide technical platforms, and only the Framework for Health Behavior Model partly relates to the potential of currently available technologies in supporting health behavior change.

Thus, in this chapter, a model informing how the suggested health behavior strategies can be translated into technological characteristics is proposed. These technological characteristics encompass all necessary technological aspects of the strategies and persuasive technology. The characteristics were distilled from the research literature on eleven fundamental theories and models related to health behavior change (HBM, TRA, TPB, SCT, SSPHL, and ELM) and fundamental theories relating technology to behavioral change (UGT, TAM, UTAUT, CBCI, and FBM). The characteristics were also distilled from 27 studies of health-based promotion programs that have shown positive results (Albaina, et al., 2009; Bickmore, Gruber, & Intille, 2008; BJ Fogg, 2007; Guerci, et al., 2003; Hurling et al., 2007; Jonathan, et al., 2006; Kirwan, Duncan, Vandelanotte, & Mummery, 2012; Klasnja, Consolvo, McDonald, Landay, & Pratt, 2009; Lau, Lau, Wong del, & Ransdell, 2011; Leahey, et al., 2010; Matthews, 2008; Medynskiy & Mynatt, 2010; Moss, et al., 1982; Plasqui & Westerterp, 2007; Raustorp, et al., 2011; Revere & Dunbar, 2001; Shuger, et al., 2011; K. Smith & Nicholas, 2008; Terry & Francis, 2007; Toscos, et al., 2008; Troiano et al., 2008; Tufano & Karras, 2005; B. Uchino, 2006; Ward, et al., 2010; Westerterp, 1999, 2009; Wilkowska & Ziefle, 2011). An extended model detailing the position of Health Persuasive Social Network in telehealth intervention context and technology context is also presented.

To identify the set of characteristics presented here, literature reviews were conducted on the seven aforementioned proposals of design principles for a health behavior change system, the eleven aforementioned fundamental theories, and the 27 aforementioned studies deploying health behavior change. From this set, the characteristics of the interventions or technologies discussed or deployed were identified, especially those which had a positive impact on the subjects of the study in terms of health behavior targets. In creating the list of characteristics, we focused on characteristics that met the following requirements:

1. Apparent relationship between the characteristics and the success of the health behavior intervention.
2. Has potential to be applied broadly across the health and wellness domain, especially to PA promotion.

3. Closely related to and having the potential to leverage the characteristics in the technologies that are currently available.

After the detailed proposal of the models are presented in this chapter, a detailed explanation of *what, why*, and *how conceptually* the suggested health behavior change strategies and design principles —which are summarized in the models— should be transformed into system requirements and further be implemented as system features is presented in Chapter 5. The explanation is called as “Framework of the Health Persuasive Social Network”. Then a detailed explanation of *how technically* the framework should be transformed into system requirements and further be implemented as system features is presented in Chapter 6, “Health Persuasive Social Network Platform”. The platform provides most of the basic and standard computer code to develop the system features so that developers do not need to build the system from scratch.

In the next sub chapter 4.1, seven fundamental and required characteristics of the Health Persuasive Social Network are presented. To make it easier to understand, a model describing the characteristics is then proposed at the end of the section.

4.1 CHARACTERISTICS MODEL

Prior to a formulation of the technologies needed to run a system, major characteristics of the system need to be identified. In this section, the seven fundamental characteristics derived from the selection and review processes described above are presented. For each fundamental characteristic, a major benefit to implementing the characteristic is identified; studies that implemented the characteristic and showed positive results are reviewed; the characteristic’s association to and consistency with the aforementioned fundamental theories/models is identified; and how the characteristic may be leveraged in the current technologies is discussed.

a) ***Personal:*** *The system should be attached or at least connected to the users whenever and wherever they are. It should also allow the user to control personal physical phenomena data, including allowing them to make decisions about to whom and for what the data will be shared. Moreover, the system should be able to deliver a personalized or tailored intervention, instead of a general or fit-for-all intervention.*

A major benefit of implementing this 'personal' characteristic is the ability to tailor care to the individual person, for example, by allowing users to choose how they would like to receive their information or even alerts. The proposal of 'personal' characteristic is also supported by findings from a few prior studies that indicate that providing personalized and tailored intervention materials will increase the likelihood of intervention to success (Kirwan, et al., 2012; Lau, et al., 2011; Shuger, et al., 2011). If we relate this characteristic with existing theories and models, it is relevant to the theoretical construct of behavioral intention (BI) of the TRA, perceived behavioral control of the TPB, and the self-efficacy of HBM and SCT. The ubiquity of the smartphone, the always-carried by and always-on nature of smart phones and the availability of connection channels anywhere means that users can perform self-management practices in situ at their convenience anytime, anywhere. It also allows users to perform self-goal setting and apply self-control by examining their condition on the feedback generated from smartphone and making changes accordingly. As the personal characteristic has been successfully used in prior PA interventions, grounding this characteristic to a mobile application for PA may increase its adoption and efficacy.

b) ***Sensible:*** *The system should give capabilities to the users to collect their physical phenomena data easily (automatically or with minimum effort) and then to store the data to an appropriate designated location with unobtrusive communication channels.*

A few prior studies have indicated that automatic data collection not only can provide accurate and detailed estimates of PA information (in some circumstances and given additional input parameters) but also can reduce the burden on users or physical educators/researchers/physicians by lessening the need for direct or manual observation (Jonathan, et al., 2006; Raustorp, et al., 2011; Shuger, et al., 2011; Westerterp, 2009). The importance of this "sensible" characteristic is also supported by a statement indicating that health self-management regimes have to take into account the accuracy of the monitoring devices, the run in period required to ensure patients are safe and effective at self-measuring, the quality assurance of the monitoring device, and the frequency with which patients are required to self-measure (Ward, et al., 2010). If we associate this characteristic with existing theories and models, it is consistent with the theoretical construct of self-efficacy, or the belief in one's own ability to do something, in the HBM and SCT (Bandura, 1977). Self-efficacy is relevant because people generally will not make attempts to do something new, for example: be more physically active, unless they think they can do it, including being able to do it consistently in long time and in required frequency. Another related and similar theoretical construct is perceived behavioral control in the TPB, where the more resources and opportunities individuals think they possess, the greater their perceived behavioral control over the behavior should be.

c) ***Real Time:*** *The system should provide the necessary information needed within milliseconds so that virtually the information is available at the time it is needed.*

A few prior studies have indicated that real-time feedback can be particularly important and useful for enhancing and then maintaining lifestyle changes of PA (Bickmore, et al., 2008; Hurling, et al., 2007; Lau, et al., 2011; Shuger, et al., 2011). If we associate this characteristic with existing theories and models, it is consistent with the principles of self-efficacy and cue to action of the HBM. This characteristic also aligns with the theoretical construct in the UGT which tells that one important gratification for people to use technology is that they can get information. As the real time characteristic has been used successfully in prior PA interventions, grounding the real time characteristic to a mobile application for PA may increase its appeal and efficacy. The implementation of this characteristic to a system for promoting PA is currently simplified by the fact that smartphones currently have enough computation power to calculate raw physical activity data generated by sensors into meaningful information for common users in milliseconds, which is virtually accepted as real time.

d) ***Secure:*** *The system should protect the confidentiality and privacy of the health related and personal data. The protection should be applied starting when the users/system perform data collection, storing processes, retrieving processes, and other processes such as processes that involve sharing information with others.*

A few prior studies have indicated that security and confidentiality play an important role for acceptance and usage of system from users (patients) and clinicians (Terry & Francis, 2007; Wilkowska & Ziefle, 2011). This security characteristic has an important role in building the trust that physical activity and health (general) data will be stored securely, which usually leads to better adherence to a health behavior change program. If we associate this characteristic with existing theories and models, it is consistent with theoretical constructs of supportive and environment factor (SCT), convenience (UGT), and perceived usefulness (acceptance) of TAM and UTAUT. Thus, as security has been used successfully and had a positive impact in prior PA interventions, grounding this security characteristic to a mobile application for PA may increase its adoption and efficacy.

e) ***Mobile:*** *The system should be able to move easily and freely together with the user.*

A few prior studies have indicated that mobile technologies that individuals routinely carry, such as mobile phones, can be a particularly effective platform for delivering PA encouragement or intervention as they are likely to be with the individual when he/she most needs the support (BJ Fogg, 2007; Revere & Dunbar, 2001; Tufano & Karras, 2005). This characteristic becomes even more important when applied to outpatient interventions, since patients can carry them easily. If we relate this characteristic with existing theories and models, it is consistent with the principles of perceived benefit, self-efficacy, and cue to action of the HBM; the perceived usefulness and perceived ease of use of the TAM, and the performance expectancy of UTAUT. As the mobile aspect has been used successfully in prior PA interventions and had a positive impact, grounding the mobile characteristic to an application for PA may increase its appeal and efficacy.

f) ***Social:*** *The system should support or provide the capability to the users to compare their performance with that of others, to have companionship, and to have social interaction in their health behavior activities.*

A few prior studies have indicated that systems facilitating social support can effectively motivate people to behavior change and effectively provide support when and where people make decisions affecting their health status (Klasnja, et al., 2009; Leahey, et al., 2010; K. Smith & Nicholas, 2008; B. Uchino, 2006). If we relate this characteristic with existing theories and models, it is consistent with principles of SCT, SSPHL, UGT, and CBCI. Those principles include the supportive environment factor, influence of belief, social categorization, cooperative interdependence, intergroup comparison, social interaction, exchange of personal information, personal attraction through similarity, sense of belonging, social enhancement, and maintaining interpersonal connectivity. As the social characteristic of health behavior change has been used successfully in prior PA interventions and had a positive impact, grounding the social characteristic to a mobile application for PA may increase its appeal and efficacy.

g) ***Persuasive:*** *The system should have the power to induce action or to encourage belief in something through reasoning or to use temptation to encourage the users to perform a desired action.*

A few prior studies have indicated that the persuasive factor in a system can indeed be effective at forming initial excitement and increasing awareness of the benefits of PA and providing motivation to increase PA levels in a fun and engaging way (Albaina, et al., 2009; BJ Fogg, 2007; Medynskiy & Mynatt, 2010; Toscos, et al., 2008). If we relate this characteristic with existing theories and models, it is consistent with the principles of cues to action (HBM), self-efficacy (HBM, SCT), perceived behavioral control (TPB), perceived behavioral control (TPB), central and peripheral routes of persuasion (ELM), entertainment and convenience (UGT), perceived ease of use (TAM), experience (UTAUT), and motivation and trigger (FBM). As persuasiveness has been implemented successfully in prior PA interventions and had a positive impact, grounding this characteristic in a mobile application for PA in may increase its appeal and efficacy.

A model of the characteristics is depicted in Figure 4-1. In summary, to effectively and efficiently motivate individuals to perform more physical activity, a system must: be able to deliver personalized and tailored intervention anywhere anytime (personal), be able to protect confidentiality and security of the data (secure), allow users to self-measure their physical activity data free of or with a minimum of effort (sensible), move easily and freely with the users anywhere (mobile), provide valid information when needed (real time), provide capabilities to the users to perform social comparisons and interactions (social), and directly or indirectly influence their behavior (persuasive). All these functions need to be in a framework to encourage users to do more physical activity.

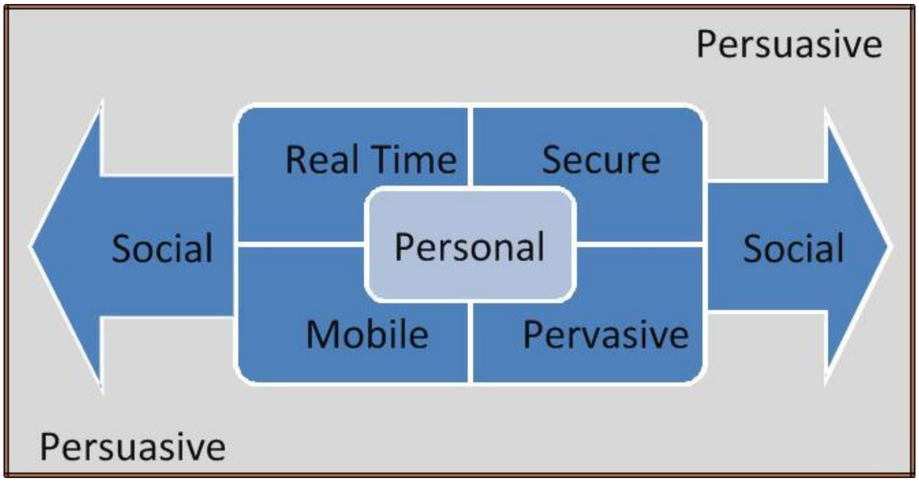

Figure 4-1. Characteristic Model of Mobile Apps for PA

4.2 INTERVENTION STRATEGIES AND TECHNOLOGY MODEL

Given the widely applied and known positive results of the health intervention strategies self-management and social support (See 3.0 and 3.2); the prior research results, theories, or models supporting the importance of the above listed characteristics (See 4.1); the proven potential of the three technologies as persuasive technology (See 3.4), an analysis to reveal the most fit currently available technologies to support the proposed seven characteristics is strongly warranted. Thus, a model called the Intervention Strategies and Technology Model (Figure 4-2) is proposed. The model can be used as guidance for a system developer when choosing the technologies needed when applying the characteristics and health intervention practices.

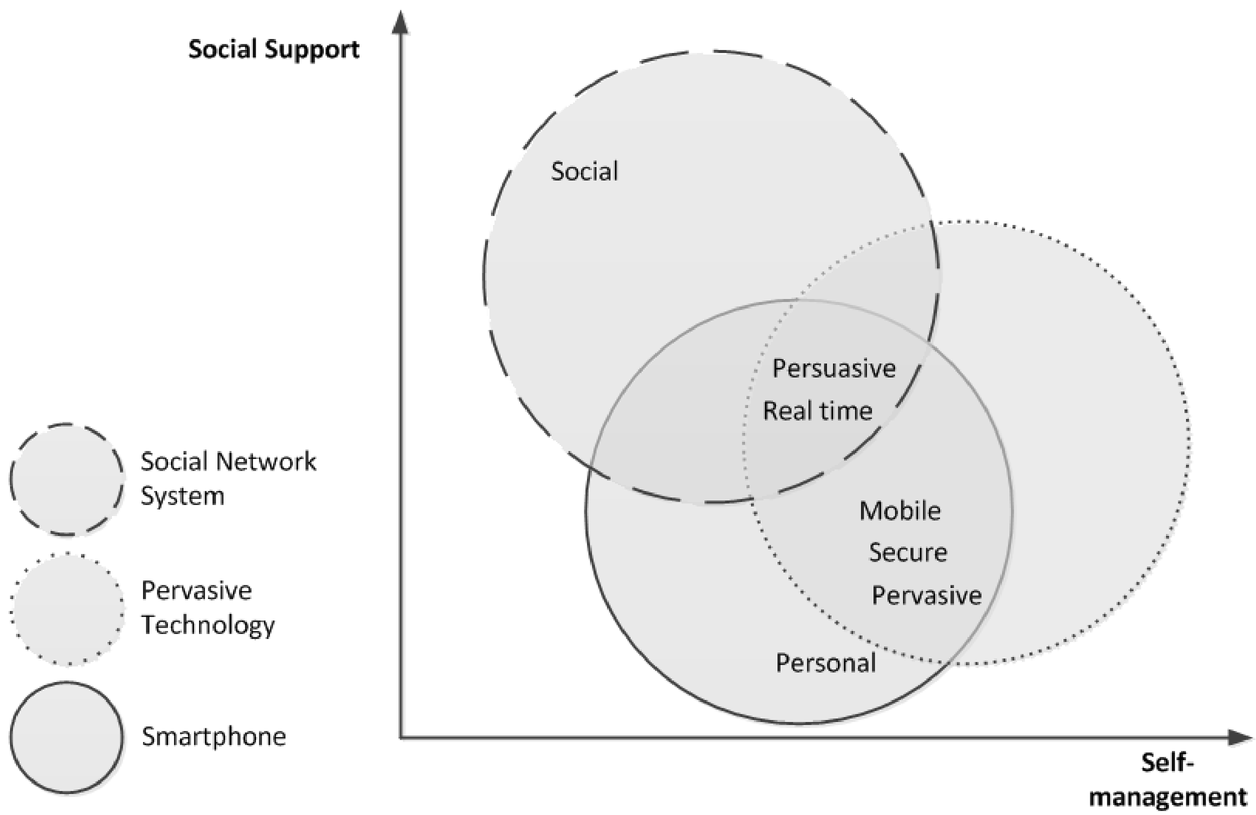

Figure 4-2. Intervention Strategies and Technology Model

In summary, the model depicts that in implementing self-management and social support as health intervention strategies, the seven characteristics can be plotted to specific areas depending on their contribution to the strategies. For example, the Social characteristic is mainly to back up social support practices; Persuasive and Real time are needed by both strategies; Personal supports mainly self-management practices; Mobile, Secure, and Sensible are needed more in self-management but sometimes or in special circumstances are needed in social support. It is possible to implement all of these characteristics effectively and efficiently because most of the technologies needed to implement them are currently available. Specifically, the currently available SNSs provide all social interactions necessary for PA promotion; persuasive and real-time are supported by SNS, sensing technology, and smartphone; mobile, secure, and sensible are supported by smartphone and sensing technology; and personal is mainly supported by smartphone.

Based on the characteristics that the platform should have (See 4.1 Characteristics Model) and their plot in health intervention strategies (See 4.2 Intervention Strategies and Technology Model), the following three currently available technologies are proposed to meet the characteristics required:

1. *Accelerometer as the Main Physical Activity Sensor*

   An accelerometer is a device that measures acceleration. Single- and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration (or g-force) as a vector quantity, which then can be used to sense orientation (because direction of weight changes) and to coordinate acceleration (so long as it produces g-force or a change in g-force), vibration, shock, and falling (in cases where the proper acceleration changes, since it tends toward zero). Currently, micro scale accelerometers are increasingly present in portable electronic devices such as smartphones (almost all smartphones released after January 2009), digital audio players, pocket cameras, and game controllers. Though the original purpose of accelerometers was to present landscape or portrait views of the device's screen based on the way the device is being held, this sensor is also can be used to produce physical activity information using some complex estimated calculations. With some additional inputs (body weight and step length), physical activity data can be generated by calculating the changes of acceleration. The information that can be generated includes number of steps, energy expenditure, distance, and average velocity (used to present physical activity intensity). Accelerometers are effective as a body sensor network (See 3.4.1) for the objective measurement of physical activity because they have the ability to continuously and automatically record physical activity data. Thus, accelerometers can not only provide objective and detailed estimates of physical activity information (in some circumstances and with additional input parameters) but also reduce the burden on users and/or physical educators/researchers compared to direct or manual observation (Guerci, et al., 2003; Matthews, 2008; Moss, et al., 1982; Plasqui & Westerterp, 2007; Raustorp, et al., 2011; Troiano, et al., 2008; Westerterp, 1999, 2009). This sensor may also allow the researcher or health professional to collect PA data *in situ*. Given these traits, the accelerometer has great potential to be used as a platform to monitor PA phenomena in health behavior change programs.

2. *Facebook as the Social Network System Platform*

Currently the most famous social network system in the World is Facebook. It has over 685 million users (1 in every 8 people on Earth), with over 250 million of these (over 50%) logging in every day; 48% of 18-34 year olds check Facebook when they wake up, with 28% doing so before even getting out of bed; the 35+ demographic is growing rapidly, now accounting for over 30% of the entire Facebook user base; the core 18-24 year old segment is currently growing the fastest at 74% a year; and almost 72% of all US internet users are now on Facebook (Facebook, 2012). Given the aforementioned numbers, the potential of using Facebook as a telehealth tool cannot be overstated. Despite the aforementioned well know potentials, most health practitioners, hospitals, and groups of users use Facebook only as a medium for sharing knowledge and discussion (Abdul et al., 2011; Amerson, 2011; Chopra & McMahon, 2011; D'Amato, Liccardi, Cecchi, Pellegrino, & D'Amato, 2010; Estus, 2010; Knezevic, Bivolarevic, Peric, & Jankovic, 2011; Kujath, 2010; Mattingly, Cain, & Fink, 2010; Odom-Forren, 2010; Williams, 2010). In addition to the phenomenal number of users which has led to the great familiarity of many people with this SNS, Facebook provides an integrated platform called Graph API by which 3rd party developers can integrate their application with Facebook (See 3.4.2). This API provides almost all necessary technical functions for online social interactions in health behavior change. Those interactions include sharing data, sharing experiences, and sending messages that can be formulated as social support mechanisms. Given these facts, Facebook is one of the best potential platforms for delivering health behavior change programs.

3. *Smartphone as the Main User Access Technology*

The steadily increasing use of smartphones, their continually improving computation power and their growing internet capabilities, the smartphone is an appropriate assistive tool to deliver a health behavior change program and should be used in this technology (See 3.4.3). From the perspective of the characteristics of PersonA, smartphones can support the following characteristics: “sensible” because currently available smartphones have a accelerometer sensor; “real time” because smartphones have enough computation power to calculate raw data generated by sensor to produce meaningful feedback to the users in milliseconds; “mobile” because this is the technology that is usually taken along by the users everywhere; “secure” because by default internet connection protocol already implements encryption to the data sent and current smartphones have password or pin functions; “personal” because smartphones are usually is carried on the person everywhere and all the time; and “persuasive” because smartphones can be used to implement persuasive design principles, self-management practices, and social support practices.

This chapter reports the position of HPSN in the health intervention context and HPSN’s characteristics. Next, a detailed explanation of *what*, *why*, and *how conceptually* the suggested health behavior change strategies and design principles which are summarized in the models should be transformed into system requirements and further be implemented as system features is presented.

5.0 FRAMEWORK OF THE HEALTH PERSUASIVE SOCIAL NETWORK

The main purpose of Health Persuasive Social Network is to translate fundamental theories and strategies in behavior change to real system features. A process to translate self-management and social support strategies into persuasive system features follows the workflow in Figure 5-1. The self-management and social support strategies were described and translated in more detail into 'proposed practices' in the literature review (See 3.1 and 3.2). The role of the Health Persuasive Social Network in the health intervention context is to enable individuals to perform the 'proposed practices' effectively and efficiently by technically translating the practices into 'technical solutions'. Each 'technical solution' is usually associated with one or more 'functional requirements'[25].

[25] 'Functional requirement' is a term usually used by software engineers; while 'technical solution' is usually used by common users or clients. They are usually interchangeable.

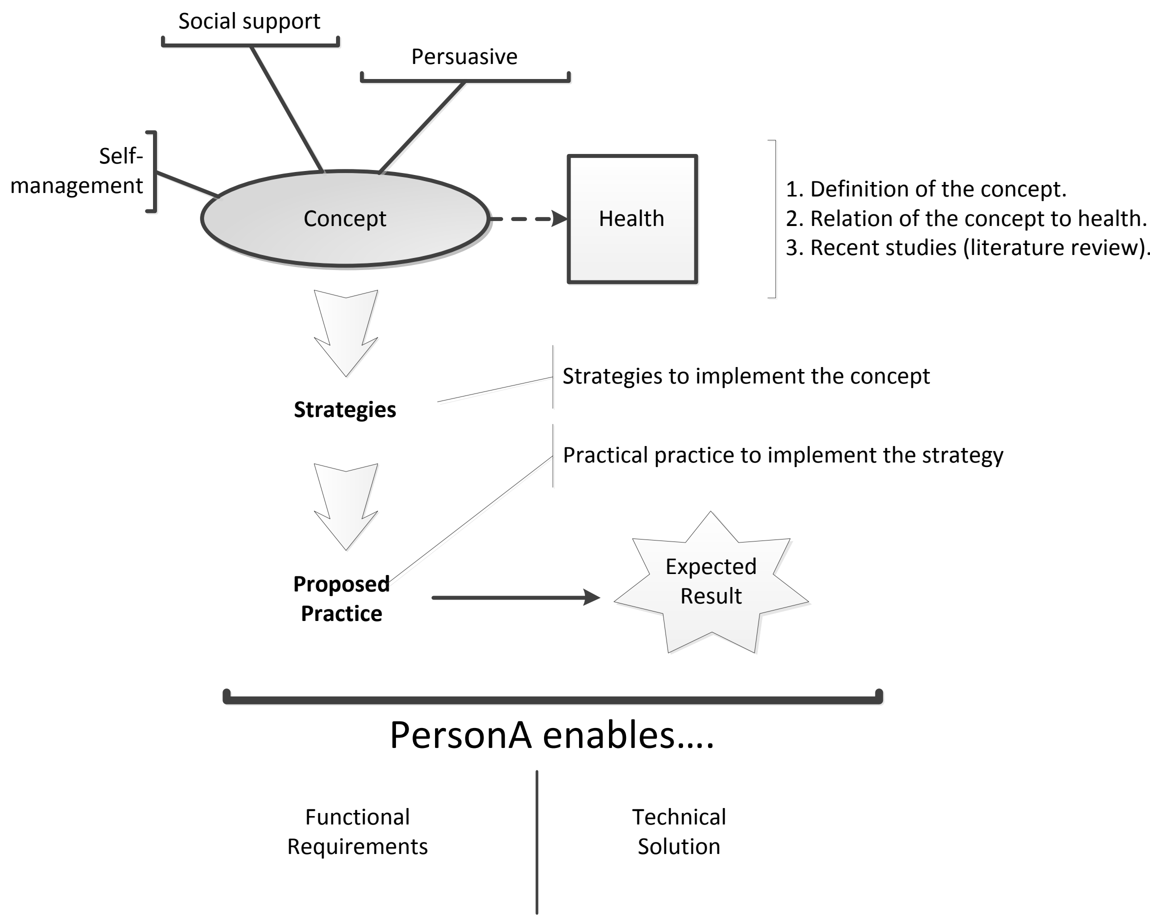

Figure 5-1. General Work flow of Concept to Functional Requirement

To achieve the purpose of enabling the Health Persuasive Social Network to act as a technology that can help users to adhere to self-management and provide social interaction for better health behavior, the following design principles —defined as the framework of the Health Persuasive Social Network— should be addressed. The design principles were distilled from the HPSN models; the six design principles studies: Functional Triad and Design Principle (BJ. Fogg, 2003), Persuasion Theories and IT Design (Marja & Oinas-Kukkonen, 2007), the Eight-Step Design Process (BJ Fogg, 2009b), Persuasive System Design (Oinas-Kukkonen Harri & Harjumaa, 2009), Framework for Health Behavior Change through Social Media (Kamal, et al., 2010), and Five Strategies for Supporting Healthy Behavior Change (Medynskiy, et al., 2011); and 42 studies of health-based promotion programs that have shown positive results (Guerci, et al., 2003; Jonathan, et al., 2006; Moss, et al., 1982; Raustorp, et al., 2011; Shuger, et al., 2011; Westerterp, 2009) (Bodenheimer, et al., 2002; Clark, et al., 1991; Locke & Latham, 2002; Ward, et al., 2010) (Bodenheimer, et al., 2002; Consolvo, Klasnja, McDonald, & Landay, 2009; Ferrier, Blanchard, Vallis, & Giacomantonio, 2010; Horowitz, Shilts, & Townsend, 2004; Kaplan, Strawbridge, Cohen, & Hungerford, 1996; Kempf, et al., 2010; Klasnja, et al., 2009; McManus, et al., 2010; North, U. Farooq, & Akhter, 2001; Rao, et al., 2010; Toscos, et al., 2008; Vogels, Egger, Plasqui, & Westerterp, 2004) (Albaina, et al., 2009; Bickmore, et al., 2008; Bravata, et al., 2007; Campbell, et al., 2004; Consolvo, et al., 2006; Edlin & Golanty, 2010; Festinger, 1954; BJ Fogg, 2007; B. J. Fogg, 2008; Hurling, et al., 2007; Jonathan, et al., 2006; Lau, et al., 2011; J. J. Lin, et al., 2006; Maitland, et al., 2006; Massoudi et al., 2010; Medynskiy & Mynatt, 2010; Mueller & Thorogood, 2007; Raustorp, et al., 2011; Shuger, et al., 2011; Terry & Francis, 2007; Toscos, et al., 2008; B. Uchino, 2006; B. N. Uchino, Cacioppo, & Kiecolt-Glaser, 1996; Bert N. Uchino, Uno, & Holt-Lunstad, 1999; Westerterp, 2009; Wiafe, et al., 2011; Wilkowska & Ziefle, 2011).

To identify the set of design principles that will be presented in this chapter, a literature review was conducted of the six aforementioned proposals of design principles of health behavior change systems and the 42 aforementioned studies on deploying health behavior change. From this set, the design principles of the interventions or technologies discussed or deployed in the proposals or in the studies were identified, especially those which gave positive impact to the objects of the study in terms of health behavior targets. In creating the list of characteristics, we focused on characteristics that met the following requirements:

1. Apparent relationship between the characteristics and the success of the health behavior intervention.
2. Closely related to and good potential to leverage the design principles in the technologies that are currently available and are potentially deployed as persuasive technology. The technologies are sensing technology, the smartphone, and a social network system.
3. Potential for the design principles to be applied broadly across the health and wellness domain, especially related to PA promotion.

In this section, the six design principles ultimately chosen after the selection and review processes mentioned above are described. For each design principle, the major benefits to implementing the principle are identified; studies implementing the characteristic and have shown positive results are reviewed; how the design principle may be leveraged in the current technologies is discussed; and system features that can be associated with the principles are conceptually proposed.

5.1 FACILITATE SELF-MANAGEMENT PRACTICES

Technical solutions to facilitate self-management are designed using the workflow depicted in Figure 5-2. The workflow was designed based on the above general work flow (See Figure 5-1). To comply with the workflow and the models of the Health Persuasive Social Network, the following four features meeting self-management strategies should be implemented in the system: Self-measurement[26], Goal Setting[27], Self-monitoring[28], and Self-comparison[29].

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[26] 'Self-measurement' refers to a feature that allows expected PA data to be captured automatically using sensor devices and then transferred to a repository.

[27] 'Goal setting' refers to a feature that helps users to define a PA goal that they want to accomplish. Using this feature, users can more easily set the realistic yet progressive PA goal for a specific time.

[28] 'Self-monitoring' refers to a feature that helps users to monitor and compare a predefined goal against the current status.

[29] 'Self-comparison' refers to a feature that allows users to monitor and compare their activity data over time. It provides a longitudinal chart which shows them a comparison between their target and its actual achievement; it also occasionally shows long-terms trends or even dips and spikes.

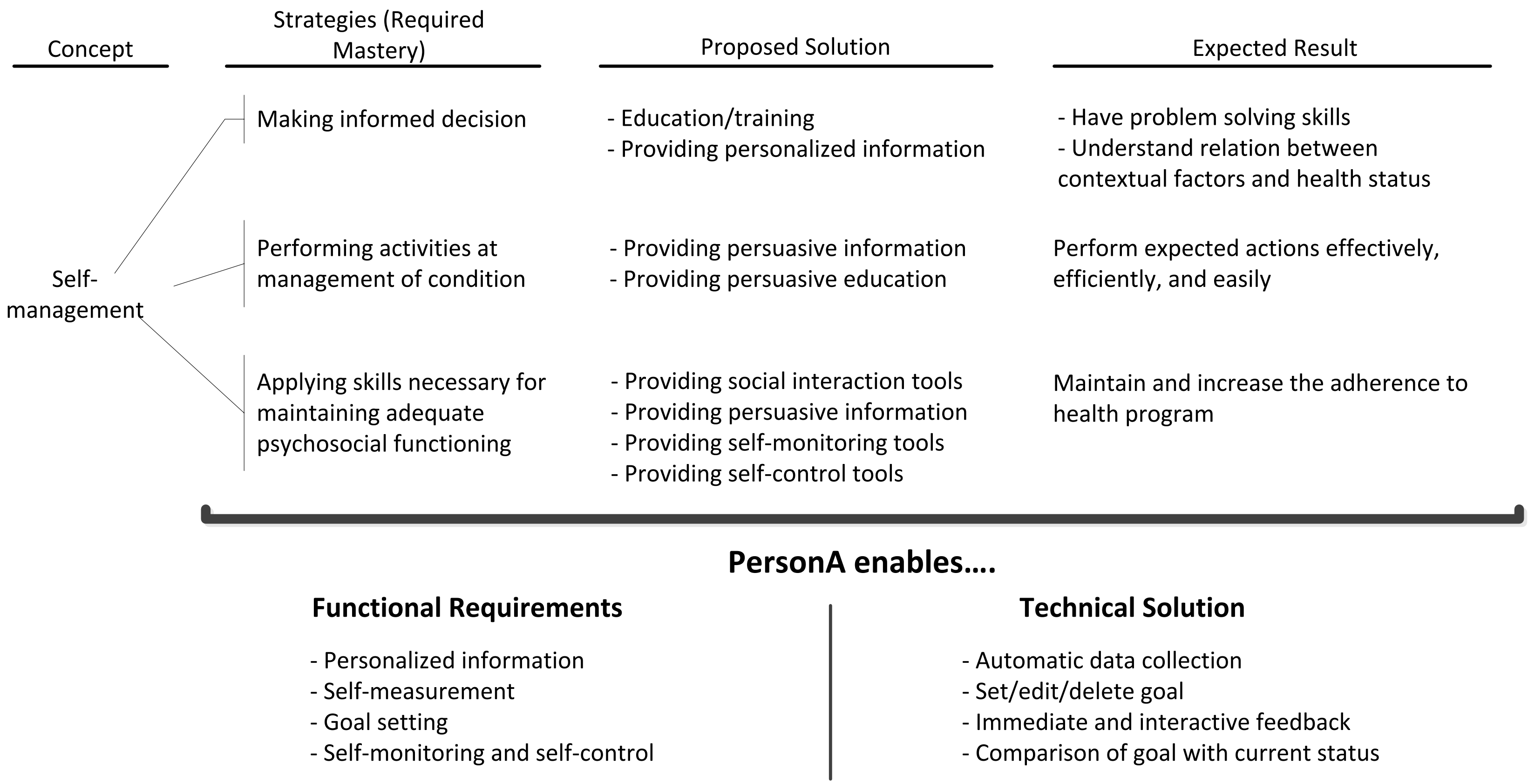

Figure 5-2. Workflow of Self-management Concept to Self-management Functional Requirements

a) *Self-measurement allows expected PA data to be captured automatically using sensor devices, which then is transferred to a smartphone. Once the data are stored in the smartphone, the data can be displayed as immediate and persuasive feedback or the data can be sent to the health portal server for further analysis or for display on the portal side.*

Self-monitoring using manual data input such as paper-pencil or even manual electronic data entry can be cumbersome and is subject to unreliable data recording because of human limitations, including being subject to biases associated with retrospective recall. As a result, low adherence to manual self-monitoring commonly occurs (Guerci, et al., 2003; Moss, et al., 1982). Automatic data collection, however, is more objective and less of a burden and so can potentially increase user's adherence to the PA program. It allows patients to measure their physical phenomena and to obtain reliable data with less dependency on health practitioners. Moreover, it reduces user's effort, and makes them more comfortable compared to using a system with manual data collection. Several studies have offered evidence to support this idea - that automatic data collection not only can provide accurate and detailed estimates of PA information (in some circumstances and with additional input parameters) but also can reduce burdens on users or physical educators/researchers/physicians compared to direct or manual observation (Jonathan, et al., 2006; Raustorp, et al., 2011; Shuger, et al., 2011; Westerterp, 2009). With respect to the self-management concept, this automatic data collection helps users to make informed decisions about their condition, which is one important mastery required to perform successful self-management (Bodenheimer, et al., 2002; Clark, et al., 1991; Ward, et al., 2010).

b) *Goal setting allows users to define a target that they want to accomplish. Using this goal setting capability, users will set a realistic PA goal for a specific time more easily and efficiently.*

Locke and Latham (2002) claimed that an individual's actions are affected by her conscious goals. In their work, a goal is defined as the object or aim of an action, for example, to attain a specific standard of proficiency, usually within a specified time limit. They concluded that the relationship between goal and performance is strongest when people are committed to their goals. The two factors that most contribute to goal commitment are (1) the importance of goal attainment to the individual, including the importance of the outcomes she expects to result from attainment, and (2) self-efficacy, that is, the belief that she can achieve the goal. Therefore if the individual does not consider the goal to be important or does not believe she can achieve it, she is unlikely to. In addition to this theory, self-efficacy as an important determinant for people's behavior is recognized in the Health Belief Model (HBM) and the Socio Cognitive Theory (SCT). In relation to health behavior change for PA, goal setting as an important determinant has been hypothesized in a few studies (Consolvo, et al., 2009; Horowitz, et al., 2004; Klasnja, et al., 2009). In general, these studies concluded that goal-setting has shown positive results in influencing people to have a more active life style. The following quote expresses this conclusion:

> *"Moderate evidence indicates that implementing goals setting as a dietary or physical activity behavior change strategy is effective with adults, and those studies that fully supported goal settings were more likely to produce positive results" (Horowitz, et al., 2004)* p.92.

Goals also serve as reference points for determining satisfaction in performance. Exceeding the goal tends to provide increased satisfaction; not reaching a goal reduces satisfaction and increases dissatisfaction. The more successful goal attainments an individual experiences, the higher her total satisfaction. Locke and Latham (2002) identified three types of goal sources: self-set, assigned, and participatively set. Performance toward a goal set for an individual (assigned) tends to be comparable with performance toward a goal in which the individual helped define the goal (participatively), provided that the assigned goal is given with an explanation of the purpose or rationale for the goal. A goal that is set for an individual (assigned) without an explanation of its purpose leads to significantly lower performance. Since there was not enough evidence to support a single type of goal-setting strategy as being most effective, a PA monitoring system should provide those three options. Given these options, users, together with clinicians or researchers, are able to choose which one is the best fit for them.

c) *Self-monitoring helps users to monitor and to compare the predefined goal and current status. It also helps users to positively self-enforce a commitment to stick with that predefined goal.*

With respect to goal setting as described in the above section, findings from a systematic review indicated that goal setting alone was not as effective as goal setting and relapse prevention combined and that the addition of self-monitoring resulted in the largest increases in PA (Ferrier, et al., 2010). Thus, the ideal scenario for this self-management is achieved when goal setting, automatic data collection, and immediate feedback are available so that users know how far they are from their target. The importance of providing feedback regarding how the individual is progressing toward her goal (self-monitoring) is also supported by Locke and Latham (2002) in their theory.

> *"For goals to be effective, people need summary feedback that reveals progress in relation to their goals. If they do not know how they are doing, it is difficult or impossible for them to adjust the level or direction of their effort or to adjust their performance strategies to match what the goal requires... goals plus feedback is more effective that goals alone" (Locke & Latham, 2002)* p.708.

This positive effect of providing comparison between target and actual achievement — defined as self-monitoring in the HPSN framework— has also been recognized in a few other studies (Ferrier, et al., 2010; Kempf, et al., 2010; McManus, et al., 2010; Rao, et al., 2010; Toscos, et al., 2008).The study by Ferrier, et al. (2010), for example, reviewed and examined the behavior change techniques that have been used in interventions to increase PA during and after completing cardiac rehabilitation. It found that four studies specifically designed to examine the effects of comparing goal and actual achievement of PA resulted in positive short-term effects on PA outcomes.

d) *Self-comparison allows users to monitor and compare their physical activity data (both target and actual achievement) over time.*

Because physical activity, as with many behavioral and biological risk factors, can change substantially over time, a one and specific time only comparison between target and actual achievement can be subject to considerable misclassification and misinterpretation (Kaplan, et al., 1996; Vogels, et al., 2004). Periodic measurement has major benefits, providing longitudinal data which shows a comparison between the target and actual achievement which, to some extent, occasionally shows long-terms trends; seasonal, temporal, environmental patterns; or even dips and spikes. This data visualization helps users to cognitively integrate and coherently understand the association between time and other attributes in the data (North, et al., 2001); in this case, the most important attribute is PA performance. It is expected that users will easily understand, get a comprehensive idea, or even increase self-efficacy about the best time for them to do physical activity. Furthermore, it is expected that knowing this relationship, to some extent, will facilitate users to make informed decisions and enable users to develop problem solving skills. It empowers individuals to improve their quality of life by helping them understand which actions and behaviors, or even which environmental factors, affect their health status (Bodenheimer, et al., 2002).

In summary, being able to self-measure, set a goal, monitor the progress toward the goal, and monitor the progressive trends over time may encourage individuals to perform better in PA. This encouragement may lead users to have better problem solving skills and better understanding of the relationship between contextual factors (e.g., time, environment) and health status (e.g., physical activity); to perform suggested actions effectively, efficiently, and easily; and finally to maintain and increase their adherence to PA promotion programs. In relation to the persuasive concept, self-monitoring is a part of an intrinsic strategy to persuade people into a behavior change (BJ. Fogg, 2003). Using self-monitoring, users can be motivated through the triggering of the intrinsic drive in them caused by setting goals, creating awareness, or conditioning through positive reinforcement. Given the strong rationale for and the positive results from the prior studies, implementing these four features as a self-management technological solution into a persuasive social network system is strongly warranted.

5.2 ENABLE ONLINE SOCIAL SUPPORT

A conceptual workflow to design the technical solutions to allow social support is proposed in Figure 5-3 based on the above general workflow (Figure 5-1). Using this social support workflow, two features meeting social support strategies were determined to strongly implemented and so were designed. Those social-support features were designed to help users with engaging in social interactions with their peers or on social networks that can positively affect their PA performance. The two features are 'social and peer comparison'[30] and 'social and peer support'[31].

a) *Peer-comparison and social-comparison capabilities compare individuals' current PA performance and target with those of others in the group, the group average, the larger community average, or the norm standard set by health practitioners.*

Willingness of an individual to make comparisons with others was recognized first by Festinger (1954). Comparison can be upward (i.e. comparing oneself to a person with greater amount of a particular quality) or downward (i.e. comparing oneself to a person with lesser amounts of that quality). Usually upward comparisons can potentially enable an individual to aspire to higher outcomes. People want to believe themselves to be part of the elite or superior and so commonly make comparisons to show the similarities between themselves and the comparison group. This upward comparison is referred to as "social acceptance construct" in FBM. Downward comparisons usually have a positive impact by boosting self-esteem. It is a defensive tendency that people use as a means of self-evaluation. These individuals will look to another individual or comparison group who are

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[30] 'Social and peer comparison' refers to a feature that allows a user to compare their PA performance with that of others, including a number of other users in a group (social) or a group member (peer).

[31] 'Social and peer support' refers to a feature that allows users to interactively support each other in performing physical activity.

considered to be worse off in order to dissociate themselves from perceived similarities and to make them feel better about themselves or their personal situation. Comparisons with others who are more similar to the self are likely to result in stronger effects of this sort. Thus, in the Health Persuasive Social Network, social comparison (comparison with other individuals with these three conditions –upward, downward, and similar) is one of most important features. In addition to providing this simple comparison, Health Persuasive Social Network also provides comparison over time (longitudinally). It is expected that the longitudinal comparison will lead to more rigorous social competition because it will not only facilitate inter-individual comparison but will also provide trends of comparison over time. The longitudinal and social interaction have been shown to usually have a stronger persuasive effect on the involved individuals than a simpler comparison (without longitudinal).

b) Peer-support and social-support capabilities allow users to support each other in performing healthier PA. Positive support activities include giving rewards or greetings for reaching a goal, sharing experiences or activities, and "liking" others' status or data.

Social interactions refer to particular forms of externalities, in which the actions of a reference group affect an individual's preferences. The reference group depends on the context and is typically an individual's family, neighbors, friends or peers. There are several reasons why social interaction is important to implement. First, although many people find it hard to open their hearts and share their feelings and problems, social interaction where people can let out their problems and feel accepted and understood is very beneficial to mental health. Another way social interaction can help health is that it can challenge distortions that we often build up through our belief systems and experiences. This positive effect of social interaction —not only social comparison— has been examined and recognized as one factor preventing disease (Edlin & Golanty, 2010; B. Uchino, 2006; B. N. Uchino, et al., 1996; Bert N. Uchino, et al., 1999). For example, Uchino (2006) explained that the interaction indirectly influences health status because people who are socially active tend to engage in behaviors that lead to a healthier life style, such as exercising regularly, which prevents disease. Recently, this premise has been examined in a few studies which use both real and online social network systems to leverage social influence and positive results were found (Albaina, et al., 2009; Bravata, et al., 2007; Consolvo, et al., 2006; J. J. Lin, et al., 2006; Maitland, et al., 2006; Massoudi, et al., 2010; Medynskiy & Mynatt, 2010; Mueller & Thorogood, 2007; Toscos, et al., 2008).

The effect of social support on an individual can be classified into four types: emotional, informational, appraisal, and inclusion support. Campbell, et al,, (2004), and Edlin & Golanty (2010) conclude that those four types result in positive effects on health management, especially by enhancing coping skills, mediating stress response, normalizing experience, providing positive role models, encouraging health behaviors, increasing self-esteem, and increasing self-confidence. It is expected that these positive social interactions would boost users' PA performance and increase the likelihood of their adherence to the program. In relation to the persuasive concept, social comparison and peer-support are implementations of the extrinsic strategy to persuade people to engage in behavior change (BJ. Fogg, 2003). Using this strategy, users will be motivated to build on social psychology where other people are the source of motivation, e.g., through competition, cooperation, or comparison. Given the aforementioned rationales and positive results from the prior studies, implementing online social support features into a persuasive social network system is strongly warranted.

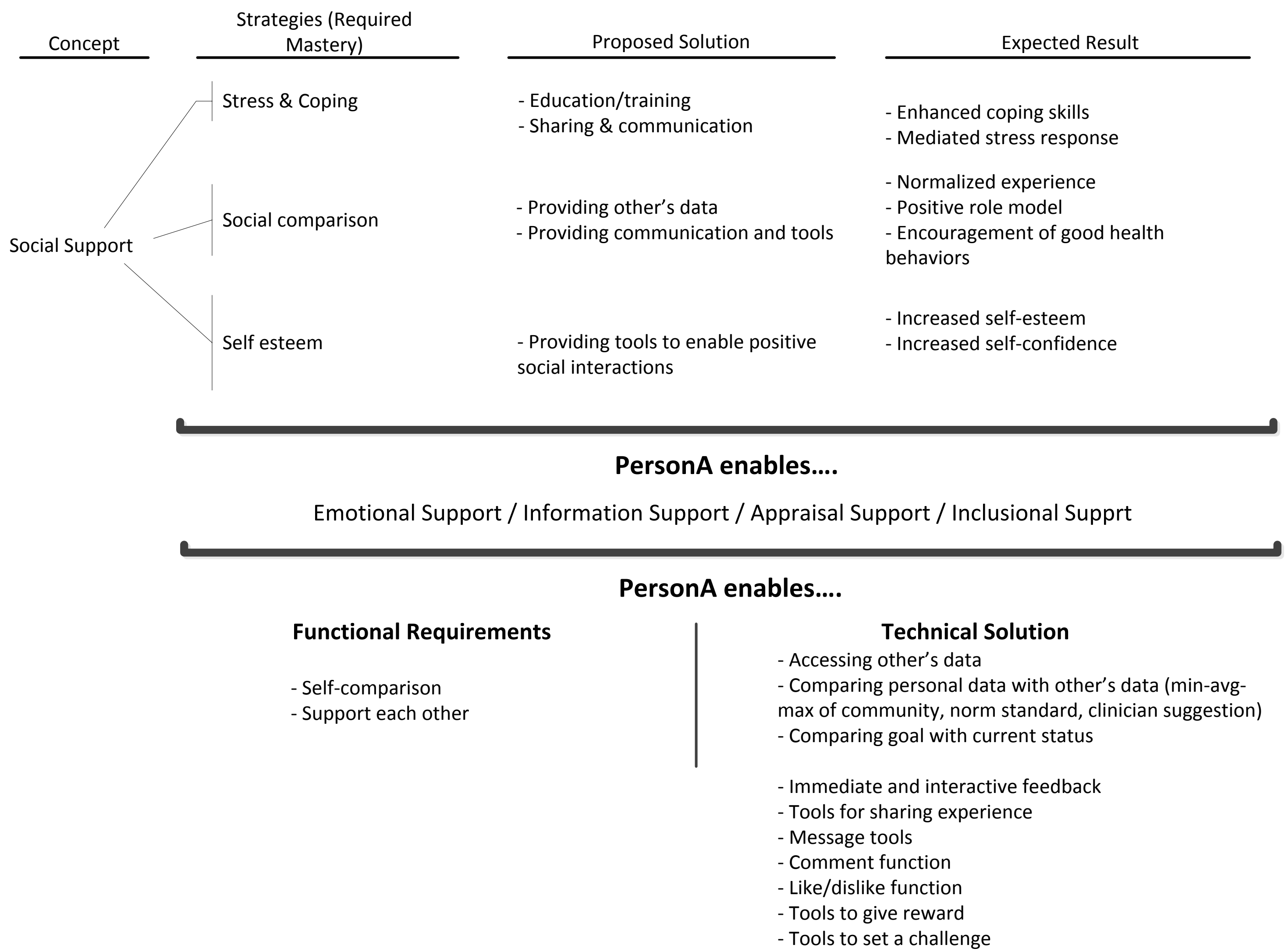

Figure 5-3. Workflow of Social Support Concept to Social Support Functional Requirements

5.3 PROVIDE AUTOMATIC DATA COLLECTION AND REAL TIME FEEDBACK

The ideal scenario for self-management and social support practices is achieved when automatic and real time data collection and immediate feedback are available so that users know how far they are from their target. Thus, to accommodate the above aforementioned features (self-management and social interaction) effectively and efficiently, the following requirements for data interaction of PersonA should be addressed.

a) *Automatic Data Collection: This data collection from sensors in sensing technologies, with the smartphone as a gateway, will be done automatically, thereby increasing the reliability of the data compared to data obtained by questionnaire or other types of self-reported data.*

Automatic data collection refers to the methods of automatically identifying objects, collecting data about them, and entering that data directly into computer systems (i.e. with very minimal or even without human involvement). A few prior studies have indicated that automatic data collection can not only provide accurate and detailed estimates of PA information (in some circumstances and with additional input parameters) but can also reduce the burden on users or physical educators/researchers/physicians compared to direct or manual observation (Jonathan, et al., 2006; Raustorp, et al., 2011; Shuger, et al., 2011; Westerterp, 2009).

b) *Immediate feedback: Providing regular, immediate, and accurate performance feedback can assist users in developing realistic expectations of their own progress by comparing their current status with their goal and also comparing their current status/goal with that of others.*

A few prior studies have indicated that real-time feedback can be particularly important and useful for enhancing and then maintaining lifestyle changes of PA (Bickmore, et al., 2008; Hurling, et al., 2007; Lau, et al., 2011; Shuger, et al., 2011). Thus, implementing this feature in the Health Persuasive Social Network is a priority. In the Health Persuasive Social Network, performance feedback is provided in a positive way and meaningful form to the users because meaningful positive changes in performance and success in achieving expected outcomes are associated with exercise adherence. Immediate feedback can be given in several forms; they can be internal (i.e., pride in accomplishment) or external (i.e., recognition). The most important function of feedback is acting as a motivator to continue goal progress.

Given the strong rationale for implementing automatic data collection and immediate (real time) feedback into a persuasive social network system and the positive results from prior studies, this step is strongly warranted.

5.4 IMPLEMENT PERSUASIVE STRATEGIES

A few prior studies have indicated that persuasive factors in a system can indeed be effective to form initial excitement, to increase awareness the benefits of PA and to provide motivation to increase physical activity levels in a fun and engaging way (Albaina, et al., 2009; BJ Fogg, 2007; Medynskiy & Mynatt, 2010; Toscos, et al., 2008). Thus, implementing this requirement in the Health Persuasive Social Network is considerably warranted. Fogg (2003) mentions that there are two strategies, intrinsic and extrinsic, that can be used to persuade people into a behavior change. Individual motivation is based on triggering the intrinsic drive of the individual, e.g., by setting goals, creating awareness, or by conditioning through positive reinforcement. Extrinsic strategies build on social psychology, where other people are the source of the motivation, e.g., through competition, cooperation, or comparison. In this study we address the persuasiveness requirements of the Health Persuasive Social Network using the following strategies adopted and modified from Fogg (2003).

1. *Bundle the system with an application that has value to the users.*

   A persuasive system can best be bundled with an application that has value to the user because value integration increases the likelihood of adoption. When individuals have a valuable system that they usually access, the persons also tend to access the other systems related to the valuable one. It does, however, present a dilemma if people choose applications with bundles of features that are appealing to them but that do not actually help them achieve their goals, or that help somewhat but not as nearly well as a different bundle of features would. There are several reasons to bundle a persuasive system with a system having value to the users. First, the system will reach a larger audience (Wiafe, et al., 2011). Second, the valuable system will create momentum and enthusiasm through a rapid cycles of access and sharing (B. J. Fogg, 2008).

2. *Provide a stratified persuasive interface.*

The Health Persuasive Social Network interface will be built to be as interactive as possible because interactive experiences that are easy and convenient to access have a greater opportunity to persuade. They tend to make users feel more comfortable about making decisions and help them act on those decisions. Two techniques that were applied are an implementing interface to increase self-efficacy to perform PA and a performance based stratified interface. The first technique was applied to give a better understanding and interpretation of the information presented so that it helps users to increase their self-efficacy. For example, an interface showing long-term trends, dips, and spikes can help users to know better when the best time for them to do PA is. The idea behind the second technique is that the users will have a more beautiful personal visualization in their home screen when they're doing better PA. For example, if their current PA status is between 60-80% of the target, the users have a more beautiful personal visualization in their home screen than when they have lower numbers. Implementing this stratified interface based on

PA performance may encourage users to perform better in PA, or at least, to have a more beautiful personal image in their home screen.

3. *Simplicity of tasks and technology increases the chances of success.*

   Reduction technologies make target behaviors easier to achieve by reducing a complex activity into a few simple steps (or ideally, to a single step). The theory behind reduction technologies is that making a behavior easier to perform increases the benefit/cost ratio of the behavior. Increasing the perceived benefit/cost ratio increases a person's motivation to engage in the behavior more frequently. In real-world design, increasing ability is not about teaching people to do new things or training them for improvement. People are generally resistant to teaching and training because it requires effort – it clashes with the natural wiring of human adults: We are fundamentally lazy. As a result, products that require people to learn new things routinely fail. Instead, to increase a user's ability, designers of persuasive experiences must make the behavior easier to do. In other words, persuasive design relies heavily on the power of simplicity.

4. *Fire a trigger at the most opportune moment.*

   The effect of a trigger in health intervention has been recognized for decades. Fogg simplifies the idea in following comment:

   > *"Without an appropriate trigger, behavior will not occur even if both motivation and ability are high." (BJ Fogg, 2009a)*. p.3.

The general concept of the trigger goes by many names: prompt, cue, call to action, and so on. The basic idea for all of these is similar: it is something that tells people to perform a behavior now. Often overlooked (or taken for granted), triggers are a vital aspect of designing persuasive products. In fact, for behaviors where people are already above the activation threshold —meaning they have sufficient motivation and ability— a trigger is all that's required. In order to achieve the optimal result, a platform will trigger users when they are most open to persuasion.

5.5 ENSURE SECURITY AND CONFIDENTIALITY

A few prior studies have indicated that security and confidentiality play an important role in user (patient) and clinician acceptance and usage of a system (Terry & Francis, 2007; Wilkowska & Ziefle, 2011). This security characteristic also has an important role in building the trust that physical activity and health (general) data will be stored securely, which usually leads to a better adherence to a health behavior change program. Given the importance of security and confidentiality in implementing health applications, grounding this feature is of paramount importance.

Above, a detailed explanation of *what, why,* and *how conceptually* the suggested health behavior change strategies and design principles should be transformed into system requirements and further implemented as system features is provided. A detailed explanation of *how technically* the transformation and transformation should be done is presented in the next chapter: Chapter 6 Platform of Health Persuasive Social Network.

6.0 PLATFORM AND SYSTEM OF THE HEALTH PERSUASIVE SOCIAL NETWORK [32]

The development of the Health Persuasive Social Network platform and systems followed the standard system development life cycle methodology (See 2.3.1). However, their development is utilized in each stage of the process to shape the system and its infrastructure according to the model and framework of the Health Persuasive Social Network. In each cycle, the development of PersonA platforms and systems follows the following conceptual and systematic stages:

1. *Identify and analyze Health Persuasive Social Network characteristics as well as functional and non-functional requirements.*

   This first stage focuses on understanding the concept of health behavior change and its practices in daily life to identify the system characteristics required to perform the change. The method to elicit the requirements includes, but is not limited to: observation of currently available health monitoring systems; interviews with people and clinicians; and literature analysis. At the end of this stage, the general and major characteristics of the

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[32]Partly published in the following papers: Ayubi, S. U., & Parmanto, B. (2012). *PersonA: Persuasive Social Network for Physical Activity*. Paper presented at the 34th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'12), San Diego, CA, USA; Ding, D., Ayubi, S. U., Shivayogy, H., & Parmanto, B. (2012). *Physical Activity Monitoring and Sharing Platform for Manual Wheelchair Users*. Paper presented at the 34th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'12), San Diego, CA, USA.

Health Persuasive Social Network and the technologies required to implement those characteristics should be identified.

2. *Design the PersonA platform based on a model, framework, and user requirements.*

   This second stage is first to create a matrix describing the relationship between characteristics, feature requirements, and technologies. The matrix consists of information on how each technology will be used to support a corresponding requirement, how the technologies will communicate with each other, and what type of data is required. This matrix directs the selection of technologies. At the end of this step, a design of integrated architecture (hardware and logical) is ready to implement. Another important process in this step is to design in greater detail the features that the system should have to meet the characteristics arrived at in the first stage.

3. *Integrate the potential technologies into a cohesive infrastructure and develop actual systems.*

   In this step, each feature requirement must have a matching technology and must be implemented into an actual system feature. The integration and implementation of security policies into the system to protect the confidentiality and integrity of information, is also warranted. At the end of this stage, complete systems with all the corresponding technologies are ready to use and test.

4. *Conduct a usability study to refine the system.*

   This stage focuses on understanding how the system is used in daily activities and whether the systems are usable. The results are usability recommendations that can be used in the next cycle of the development process to refine the system.

6.1 PLATFORM DESIGN

Based on the major characteristics of the system (See 4.1 Characteristics Model) and the technologies that may fit with the characteristics (See 4.2 Intervention Strategies and Technology Model); the hardware architecture, logical architecture, and communication platform to integrate the technologies are proposed as follows.

6.1.1 Architecture

6.1.1.1 Hardware Architecture

The PersonA hardware architecture consists of sensing technology as data point of input (Data POI), a personal gateway, a portal server, a social network system bridge (SNS Bridge), and a Facebook server.

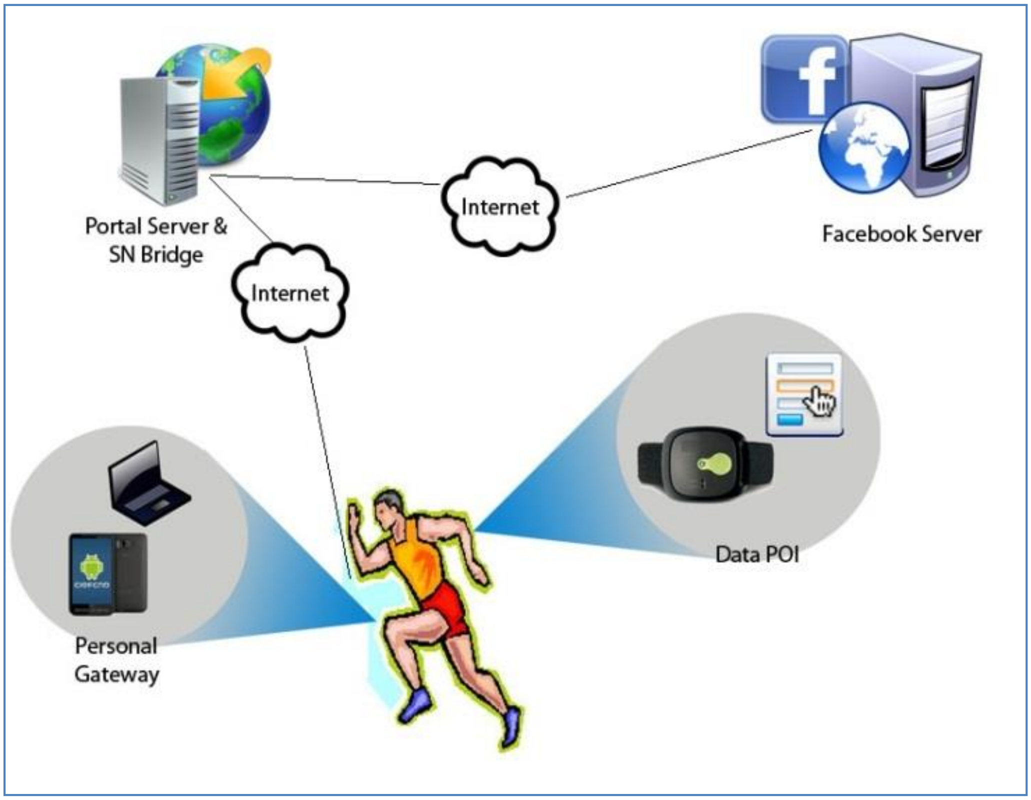

Figure 6-1. PersonA General Architecture

The data POI consists of sensory devices, or tools feeding data to the PersonA, e.g. a physical phenomenon sensor (accelerometer and gyroscope) or a contextual-environment sensor (weather sensor and GPS). The sensors communicate with the personal gateway using Bluetooth, unless the sensors are integrated with the personal gateway. The personal gateway stores the sensory data temporarily, analyzes them, shows any post-analyzed and meaningful feedback, and transmits the data to the remote portal server where the data will be stored. Because HTTP protocol is used in data transmission from the personal gateway to the portal server, the gateway must have Internet connection services such as GPRS, 3G, or WLAN. The Android smartphone was chosen as a primary personal gateway because the Android operating system (OS) is free, open-source, easy to develop applications on, and a predominant OS on smartphone devices (Nielsen Consulting, 2011). The portal server uses distributed database architecture to store the sensory data mapped with user profile data. In addition to acting as a data repository, the portal server also acts as web server that hosts the PersonA web system and web services. The SNS Bridge is a system connecting the secured portal server or personal gateway with the social network system (Facebook) server. A detailed design of the SNS Bridge is described in Section 6.1.1.2 and 6.1.1.3.

6.1.1.2 Logical Architecture

The logical architecture of PersonA consists of three parts: System-User Interaction (SUI), Data Management and Logical Functions (DMLF), and Social Network System (SNS). The visualization of this logical architecture is depicted in Figure 6-2.

System-User Interaction (SUI)

The SUI has two main parts: an input part and a viewing part. The input part is designed to depend largely on automatic data input methods. In the implementation, the physical phenomena and contextual data are designed to be received from the Data POI automatically and intelligently. For example, PA data (steps, distance travelled, energy expenditure, average velocity) and contextual information (temperature, location, etc.) can be captured using sensors integrated into currently available smartphones. In case automatic input is not possible, because of technology or procedural limitations, a manual method is provided. The manual processes are mainly performed by the users. These include setting a goal (PA target), and setting up height and weight, as well as communicating and interacting with others in ways such as giving a comment, sending a message, or setting a challenge.

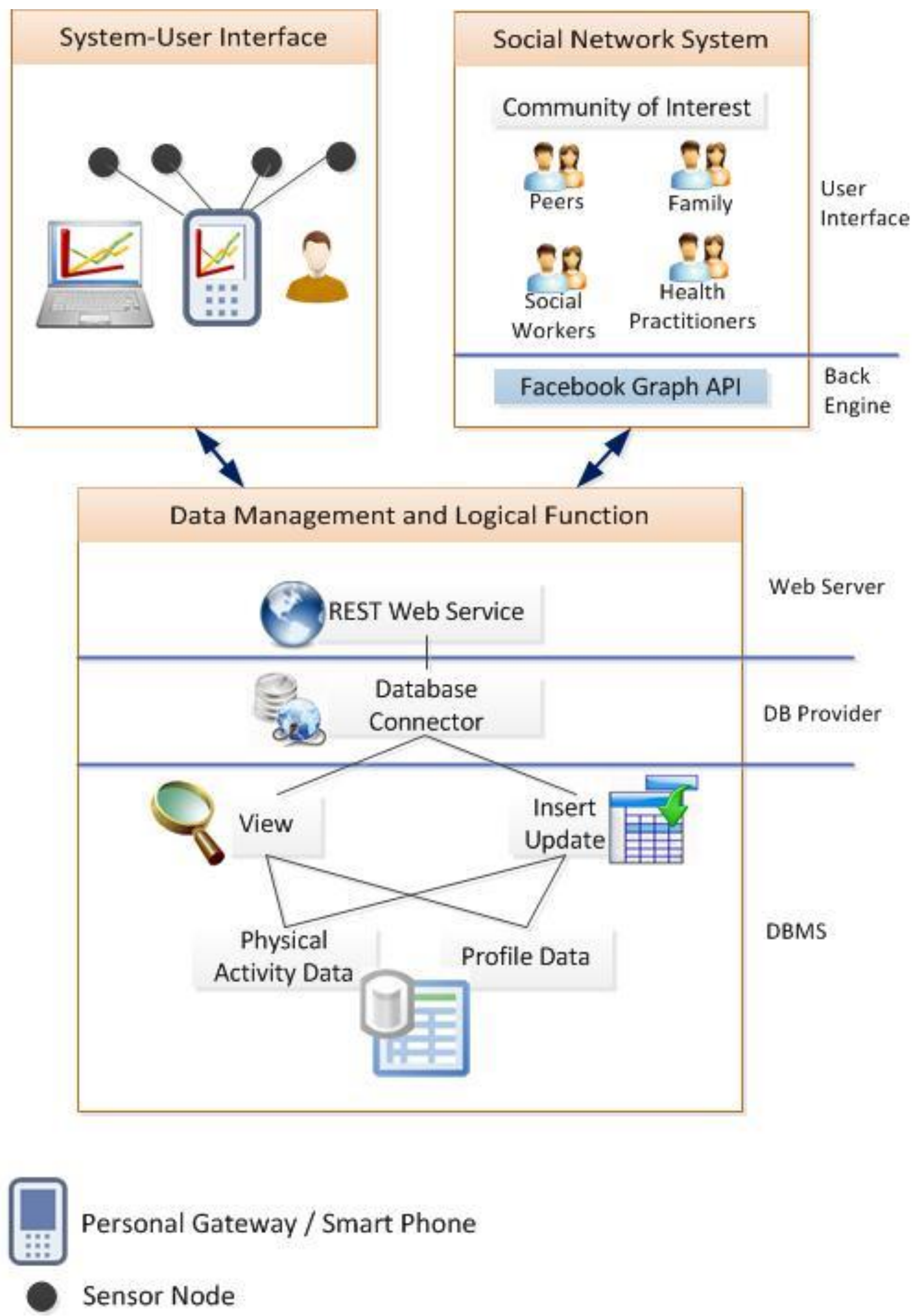

Figure 6-2. Logical Architecture

The viewing part consists of the two main interfaces of PersonA: an Android-based mobile application and a web page. The mobile application of PersonA will be the primary interface. The mobile interface consists of four main menus (Figure 6-3): home, personal, social, and settings.

This separation is to allow simple navigation between activities when accessing PersonA. The home menu acts like dashboard where users can view the primary and the most important information easily at a glance such as current number of steps and its progress towards the goal. The personal menu provides users with the capability to input personal information such as weight and height; to set up PA goals; and to view their PA over time. The social menu allows users to perform social comparison, social competition, and social communication. Finally, the settings menu enables users to set up PA goals and to set up application properties not related directly to PA such as operating level, voice feedback, etc.

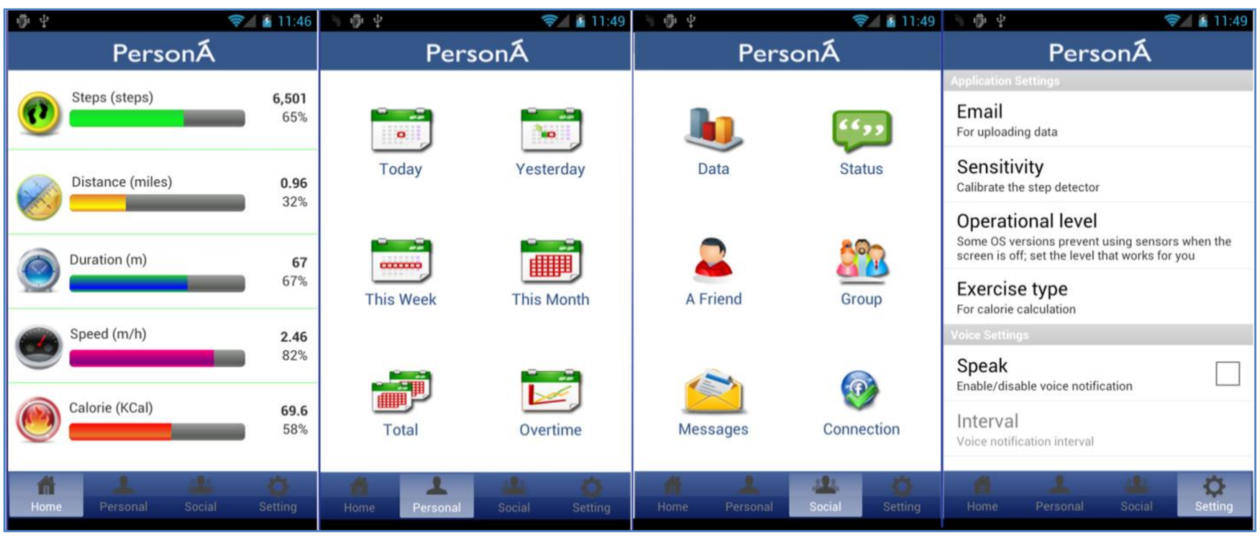

Figure 6-3. PersonA Mobile Apps Interface for SocioPedometer

As the second main interface, the web interface of PersonA is embedded into Facebook using an IFrame component. The IFrame is an HTML structure that allows one HTML page to be inserted into another HTML page. In this case, the PersonA page is inserted into the Facebook page (See Figure 6-4). The web version is designed to contain the extended-view tools of PersonA, where users can have a bigger view and extended functionality with respect to self-management and social interaction activities compared to that of the mobile version.

Figure 6-4. PersonA Web Interface

Data Management and Logical Functions (DMLF)

The main functions of the DMLF are to capture data from the personal gateway; to store or to update data in the database management system (DBMS) using the 'Insert/Update' command, and to provide post-analyzed and post-calculated information using the 'View' command upon the request of users. The DMLF consists of the REST web service, a database connector, and a database management system (DBMS). Representational State Transfer (REST) is an architectural style that is used to access any resource from the web. REST has the following unique design advantages: it is easy to manage and access because each data is represented by a unique Uniform Resource Identifier (URI) and each URI can be accessed using HTTP protocol; and REST is very lightweight data size in comparison to Simple Object Access Protocol (SOAP) messages. The web service acts like a front page for a database system server by which users, using the PersonA system, can request or store data. The PA data, profile information, and other related data are stored and managed in DBMS. Microsoft SQL Server 2008 was used because it is seamlessly integrated with Microsoft technologies, is secure, and is relatively cheap (Express edition is free). A Microsoft Database Connector was used as a bridge connecting front page (REST web service) and DBMS.

Social Network System (SNS)

The social network part handles the interaction between PersonA and Facebook as a platform to run social interactions. Facebook was chosen because it is the most popular social network and also has an open application-programming interface (API), called Graph API, through which PersonA can communicate and use as a platform for online social interactions. The API provides almost all of the functions to perform necessary online interactions needed in social support of PA promotion. This API also allows other systems, such as PersonA, to use the Facebook's authentication, security settings, and privacy/confidentiality settings.

6.1.1.3 Communication Platform

The idea of a communication platform is to integrate current advanced technologies: sensing technology, smartphone, portal technology, and social network systems. This integration allows health related data to be dynamically, effectively, and efficiently transferred among these various technologies. The general design of this platform is illustrated in Figure 6-5 below. The sensing technology has a rule to capture any physical phenomena of the human body including, but not limited to, energy expenditure (EE), distance travelled, and average velocity of wheelchair users. The connection protocol between the sensing technology and personal gateway (smartphone) is Bluetooth, which enables data to be transferred in near real-time but does not require extensive computation power. In addition to serving as a connector between the sensing technology and the health portal, the smartphone will also be designed to work as temporal data repository that manages data collected from the sensing technology. The data will be stored in the smartphone for a specific period and then will be transferred to the health portal.

The data transfer between the health portal and the social network system (Facebook) uses a standard Internet connection and modified-Graph API. The API provides a simple function of social interaction, users, the connections among users, and online interaction among users (e.g., comments, messages, data access, and photo or article tags).

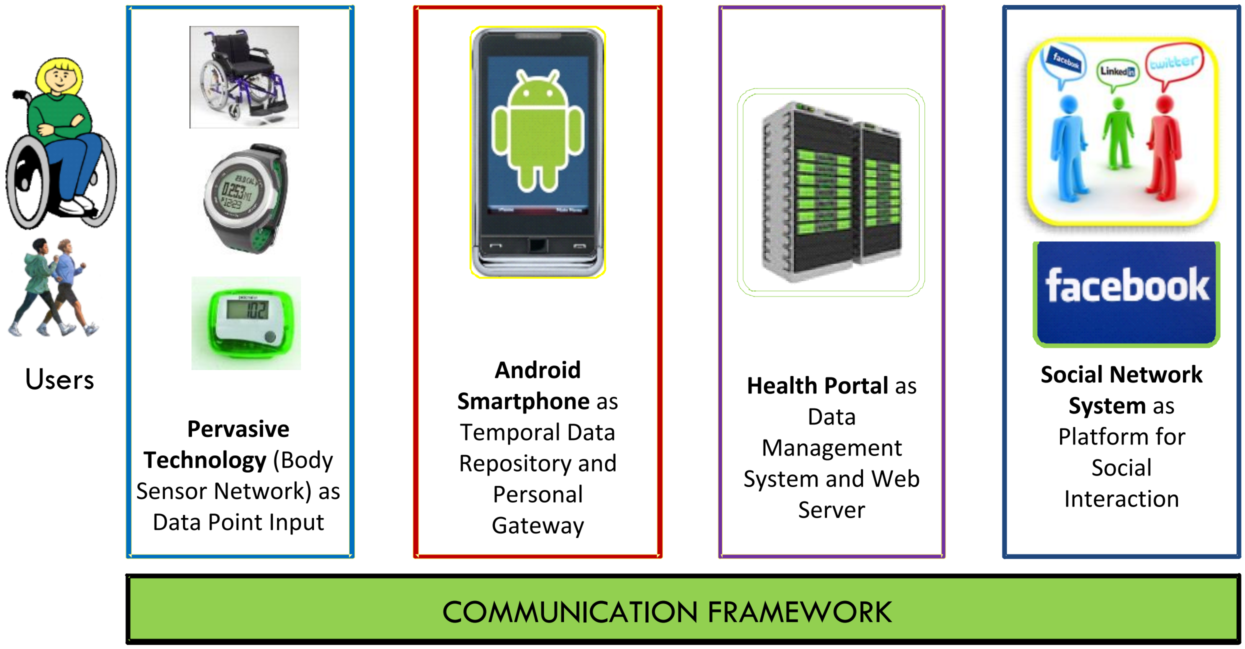

Figure 6-5. PersonA Communication Platform

The main purpose for developing the PersonA communication platform was to take advantage of the strength and capacity for supporting PA promotion of each technology involved as well as to guarantee that data transfer among those technologies can be performed smoothly, effectively, and efficiently. From the technical perspective, there are three parts to the PersonA communication platform: Personal Gateway – Portal Server, Personal Gateway – SNS, and Portal Server – SNS. This partition is not visible from a logical perspective; what is visible is a simple communication between users with all attached sensors and COI (Figure 6-6).

Personal Gateway – Portal Server

The communication between the personal gateway and portal server is initiated when PA data is sent from the personal gateway to the portal server or when PA information is downloaded from the portal server to the personal gateway. The data is sent to the server through the HTTP POST

RESTful web service. A similar function is also executed when users request to download data from the portal server to the personal gateway.

To simplify and reduce data size, the JSON format was chosen as data format instead of XML or other formats. JSON (JavaScript Object Notation) is a data-interchange format (JSON.org), making it is easy for humans to read and write and easy for machines to parse and generate. In addition, JSON is a text format that is completely language independent, but uses conventions that are familiar to programmers of the C-family of languages, including C, C++, C#, Java, JavaScript, Perl, Python, and many others. These properties make JSON an ideal data-interchange language.

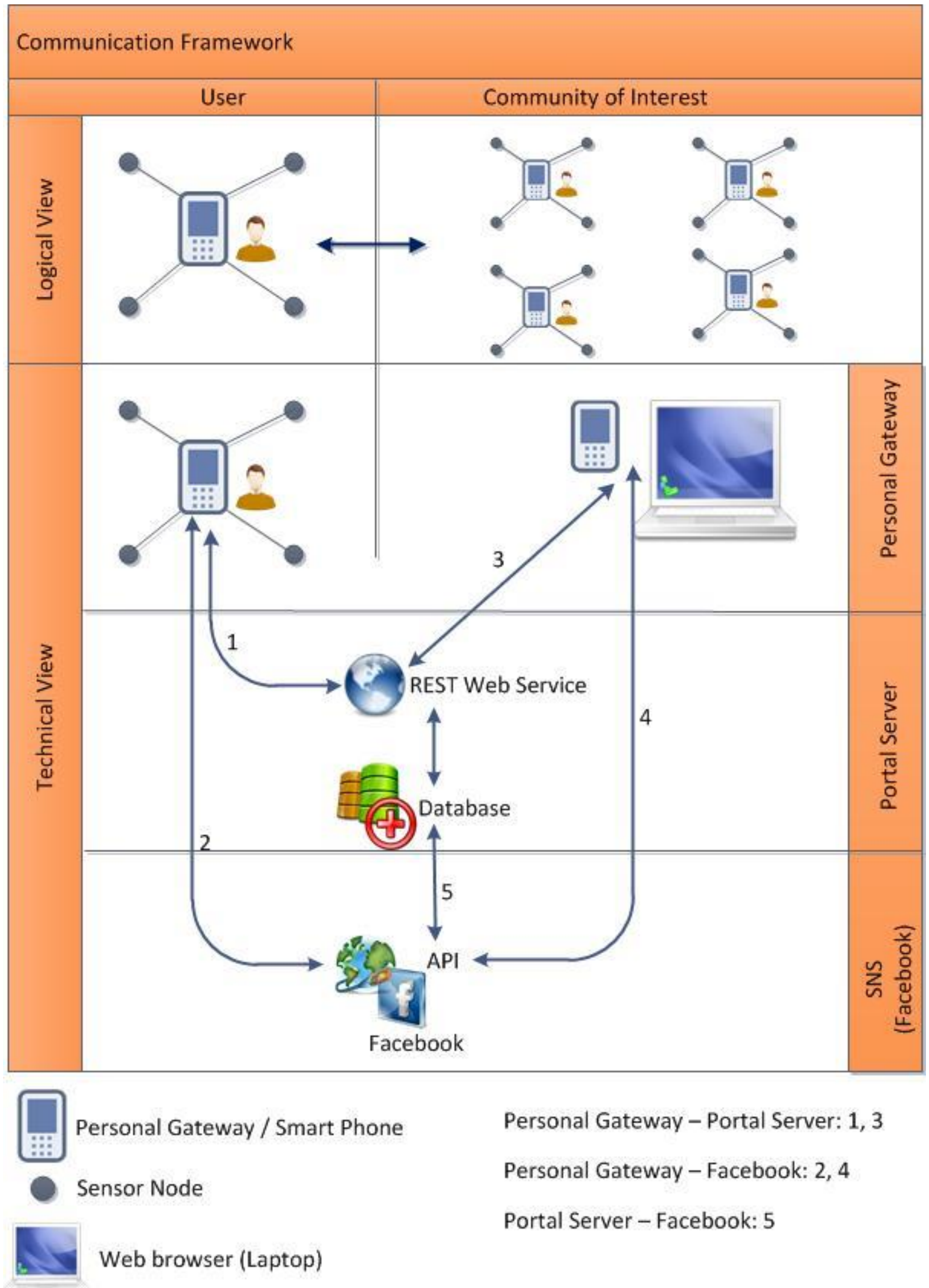

Figure 6-6. Technical and Logical View of the Communication Platform

Personal Gateway – SNS (Facebook)

Personal gateway and Facebook communication is initiated several times, for example when the PersonA system needs to use login processes and social network functions. At first, when a user tries to use the system, the login page from Utility in Facebook Graph API is called. To make PersonA more seamlessly integrated with Facebook, several other functions are also called when the following actions are executed:

1. The Feed function is called when posting PA information to the user's own page, another member in Persona group, or to all Persona group members. The http format for this function is: https://graph.facebook.com/PROFILE_ID/feed
2. The Group function is called when trying to get group information and also when posting PA information to group members. The http format for this function is: https://graph.facebook.com/GROUP_ID
3. The Comments function is called when giving comments about PA information. The http format for this function is: https://graph.facebook.com/OBJECT_ID/comments
4. The Like function is called when "liking" PA status or information. The http template for this function is: https://graph.facebook.com/OBJECT_ID/likes

Portal Server – SNS (Facebook)

Communication between the Portal Server and Facebook is used to perform all social network functions in the PersonA web version. The functions of Graph API and which PersonA functions initialize those functions are exactly the same as those in the Personal Gateway – Facebook description, but unlike with Personal Gateway – SNS communication, the social support functions are performed by the Portal Server.

6.1.2 Functional and Non-Functional Features

Based both on Health Persuasive Social Network models (See Chapter 4) and the Health Persuasive Social Network framework (See Chapter 5), two versions of PersonA were developed. The first version was developed on top of a web platform; the second version was developed on top of the Android smartphone. As mentioned above, the mobile version acts as the primary system used to perform all self-management and social interaction practices while the web version was designed as an extended-view tool where users can have bigger views and extended functions of self-management and social interaction activities. The description for each (feature) follows.

6.1.2.1 Self-management Functional Features

Following the guideline from the HPSN framework (See 5.1), three PersonA features are proposed: Self-measurement, Goal Setting, and Self-monitoring. A detailed description of each capability and its screenshots follows this section. Because PersonA has two interfaces, smartphone and web, the screenshots are from either the smartphone or the web interface.

1) Self-measurement allows expected PA data to be captured automatically using sensor devices and then transferred to a smart phone. Once the data are stored in the smart phone, they can be displayed as immediate and persuasive feedback or they can be sent to the health portal server for further analysis or for display on the portal side. The automatic data collection can potentially increase user's adherence to the PA program. It allows patients to measure their physical phenomena and to obtain reliable data without having to depend so much on health

practitioners. Moreover, it reduces user effort to input the data compared to using a system with manual data collection.

2) Goal setting allows users to define a target that they want to accomplish. Using this goal setting capability, users will be able to set a realistic PA goal for a specific time more easily and efficiently. Figure 6-7 illustrates the interface of PersonA where users set their goal. Before setting their goal, however, users can compare the new target they want to accomplish with the one that was already set. Comparing the two may encourage them to set and accomplish a better goal.

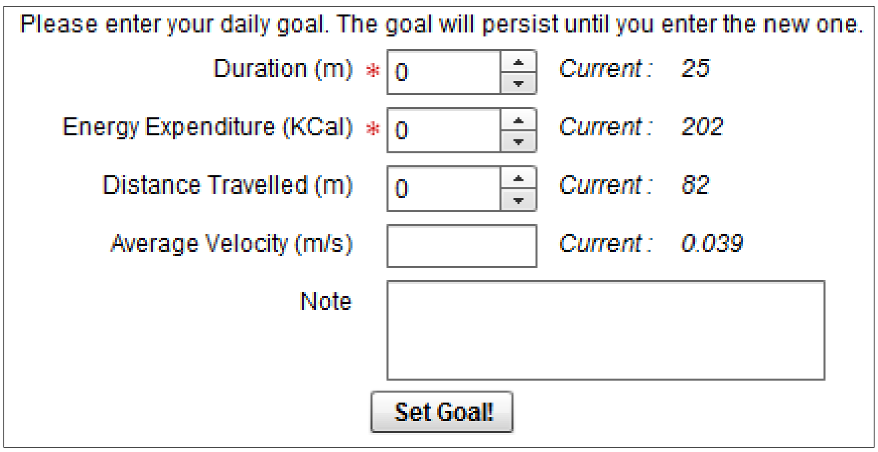

Figure 6-7. Goal Setting Screen

3) Self-monitoring helps users to monitor and to compare the predefined goal and current status. It also helps users to positively self-enforce a commitment to stick with that predefined goal. The ideal scenario for this self-management is when automatic and real time data collection and immediate feedback are available so that users know how far they are from their target. The self-monitoring chart below (Figure 6-8) shows how users can easily check the actual number/value for each activity item while they are performing a physical task. They can also monitor the progress they make by looking at the progress bar for each item and its percentage

count, all on the same screen. The progress bar was chosen as the means to convey progress for the physical activity tasks the user performs. For example, Figure 6-8 shows that the user has reached 0.96 miles distance, which is 32% of their target.

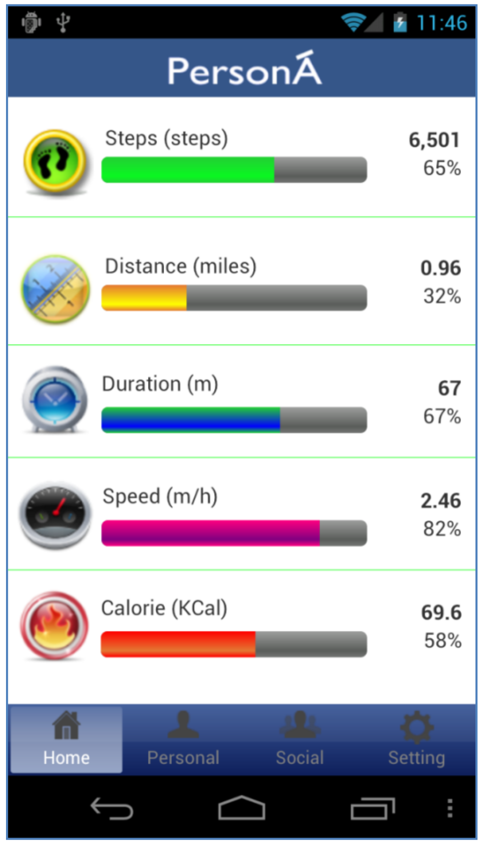

Figure 6-8. Self-Monitoring Screen

Users also have access to a longitudinal chart which illustrates their progress to date in reaching their PA target. This occasionally shows them long-term trends or even dips and spikes (Figure 6-9).

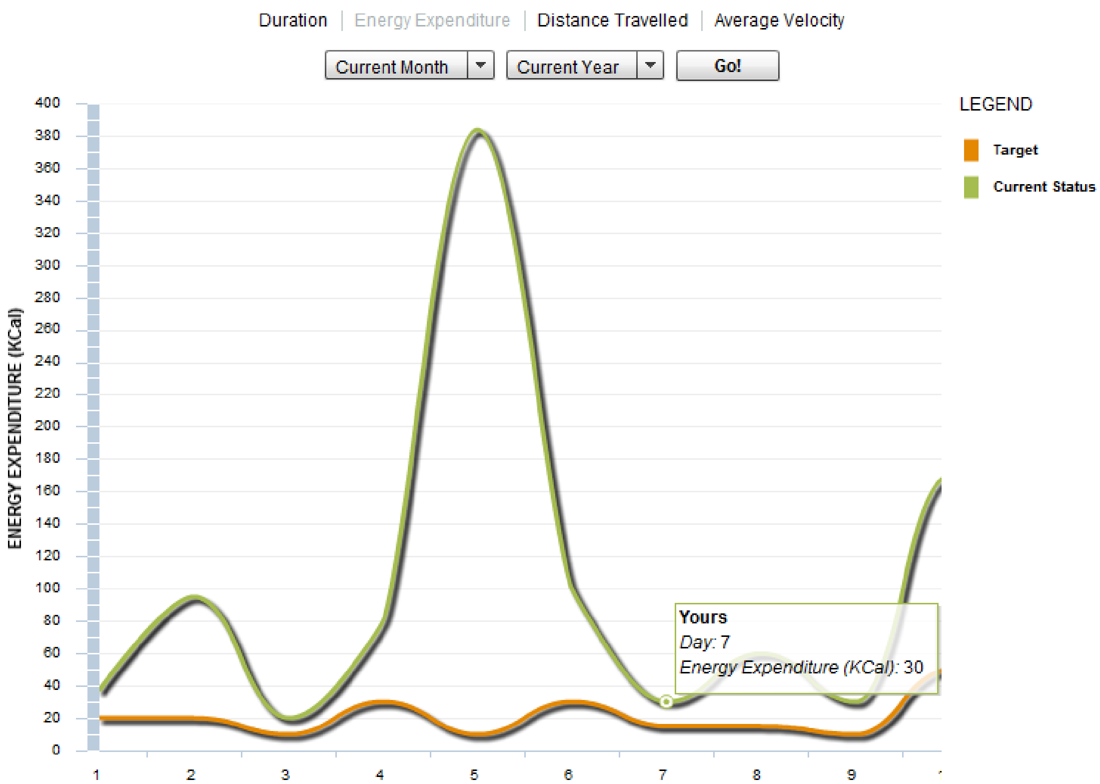

Figure 6-9. Self-Monitoring Screen (Longitudinal)

Being able to monitor all of these activities may encourage the users to perform better in PA. In relation to the persuasive concept, self-monitoring is part of the intrinsic strategy to persuade people into a behavior change (BJ. Fogg, 2003). Self-monitoring will motivate the users by triggering the intrinsic drive in them, which is accomplished by allowing users to set goals, by creating awareness, or by conditioning through positive reinforcement.

6.1.2.2 Social Interaction Functional Features

Following the guidelines proposed in the HPSN framework (See 5.2), two PersonA features were designed with the main purpose of helping users to engage in social interactions with their peers or social networks that can positively affect their PA performance. These two features are social-peer comparison and social-peer support.

1) Social-peer comparison is a way to compare an individual's current PA performance with the performance of others in a target group through the group average, the larger community average, or the norm standard set by health practitioners. Figure 6-10 illustrates a "calories burned" chart that compares the summary of the user's energy expenditure with that of others in the social network. The chart also provides a comparison longitudinally. We expect that this kind of comparison will lead to rigorous social competition as it is usually more persuasive than a simpler comparison.

Figure 6-10. Social Comparison Screen

2) Social-support and Peer-support capabilities allow users to support each other in their goal of performing healthier PA by allowing users to give rewards or greetings for reaching a goal, to share experiences or activities, to "like" others' status or data, and to perform other positive support activities. As an illustration, Figure 6-11 shows that users can share their selected data

with a friend (left), group members (middle), or even all friends on their Facebook (right); and once the information is posted on a Facebook wall, a friend can give a comment (a positive one is expected) and "like" the post.

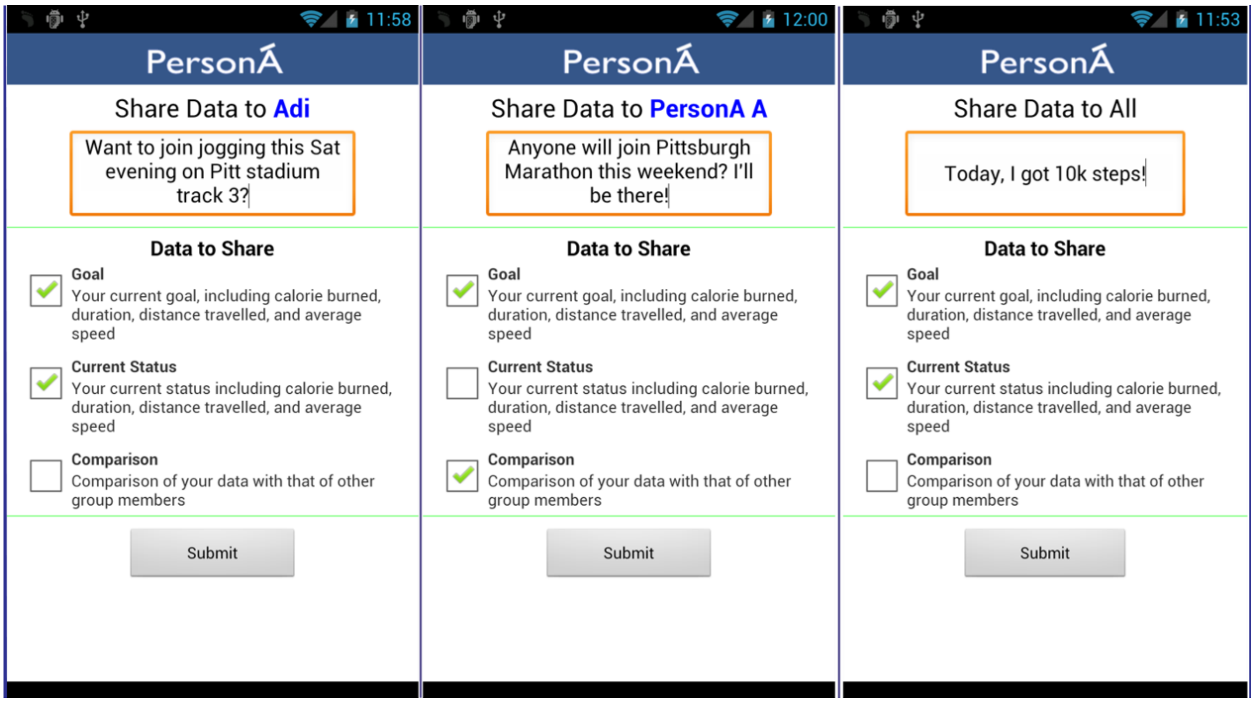

Figure 6-11. Sharing with Community of Interest (COI)

Figure 6-12 illustrates what their friends see on their Facebook page.

Figure 6-12. Social Support Screen

It is expected that these positive social interactions boost users' performance and increase the likelihood of their adherence to the program. In relation to the persuasive concept, social comparison and peer-support are an implementation of the extrinsic strategy to persuade people to engage in behavior change (BJ. Fogg, 2003). Using social comparison and peer support, the users will be motivated by social psychology, where other people are the source of the motivation, e.g., through competition, cooperation, or comparison.

As a summary, PersonA capabilities designed to meet the functional requirements are depicted in the following Figure 6-13.

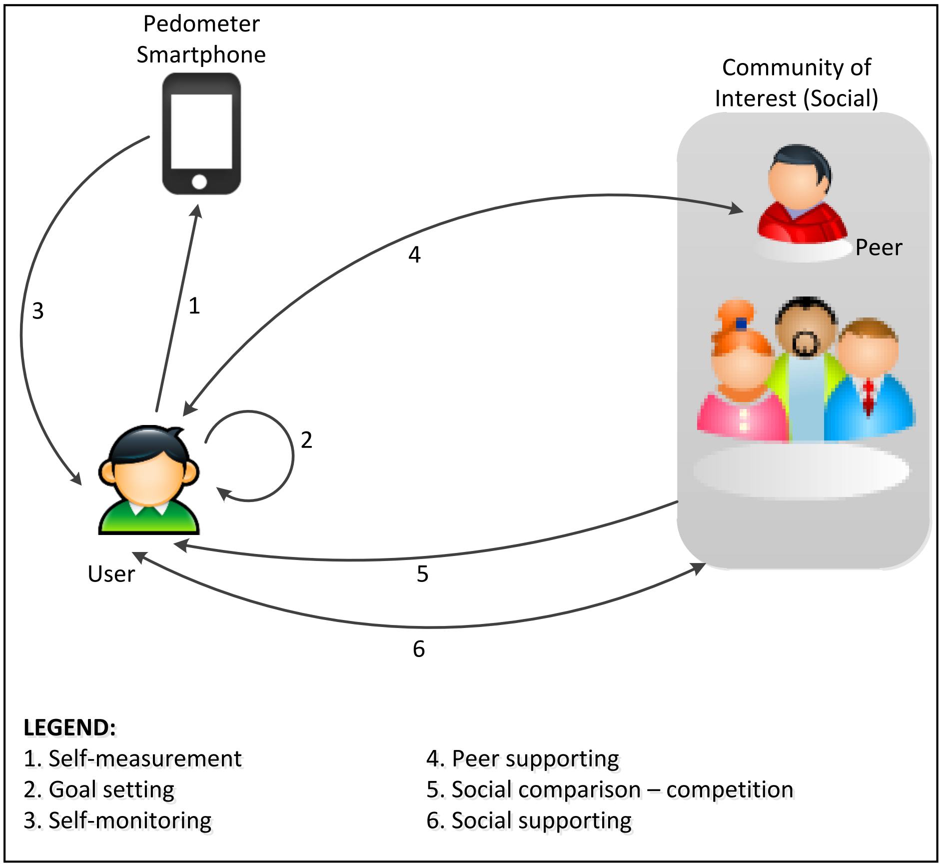

Figure 6-13. PersonA Functional Requirements

6.1.2.3 Sensor-based Input and Mobile Interface Feedback

The ideal scenario for self-management practices is when automatic and real time data collection and immediate feedback are available so that users know how far they are from their target. Thus, to accommodate above the aforementioned features (self-management and social interaction) effectively and efficiently, the data interaction requirements of PersonA summarized in the following table should be addressed:

1. *Automatic data collection:* This data collection from sensors in sensible technologies, with a smartphone the gateway, will be done automatically; this can increase the reliability of the data compared to questionnaire or self-reported data. Since the most widely used commercial systems are not open to third party developers (See 3.4.1), the best candidate for capturing PA data in this research was the accelerometer (See 4.2 a). Using some complex and estimated calculations, this sensor can be used to produce physical activity information. Specifically, using some formulas and other parameters such as body weight and step length, physical activity information calculated using movement factors such as number of steps, energy expenditure, distance, and average velocity (used to present physical activity intensity) can be produced. Accelerometers are effective tools to be used in a body sensor network (See 3.4.1) for the objective measurement of physical activity because they have the ability to continuously and automatically record physical activity data. Another potential tool is a ready to use system such as Wocket (Intille et al., 2011). This wocket can be used and customized, especially for a non-general population such as the wheelchair population (Ding, et al., 2012). Together with a wheel rotation monitor (WRM), a wocket provides complementary information about physical activity in wheelchair users and allows more comprehensive and accurate assessment of multiple PA measures in this population.
2. *Immediate feedback:* Providing regular, immediate, and accurate performance feedback can assist users in developing realistic expectations of their own progress by comparing their current status with their goal, and also comparing their current status/goal with others. Technically, the smartphone can be used to provide immediate feedback because it has enough computation power to use raw data generated by sensors to calculate and communicate meaningful feedback to the users in milliseconds, which can be considered real time. The smartphone also has mobile characteristics which enable users to get the feedback from anywhere —additionally the smartphone has internet connectivity that enables it to communicate with other technologies, such as a server, so that the immediate feedback from servers can be downloaded from anywhere.

6.1.2.4 Integration, Interactive-Stratified Interface, and Simplicity as Persuasive Techniques

Fogg (2003) mentions that there are two strategies, intrinsic and extrinsic, that can be used to persuade people into a behavior change. Individual motivation is based on triggering the intrinsic drive of the individual, e.g., by setting goals, creating awareness, or by conditioning through positive reinforcement. Extrinsic strategies build on social psychology where other people are the source of the motivation, e.g., through competition, cooperation, or comparison. Apart from intrinsic and extrinsic persuasion strategies, in this study, we address the persuasiveness requirements of PersonA using the following strategies, adopted and modified from Fogg (2003).

1. A persuasive system would best be bundled with an application that has value to the user, because value integration increases the likelihood of adoption. Therefore, PersonA is integrated with the most popular social network system, Facebook. Integrating PersonA with this famous SNS should increase its persuasive effect in promoting PA (See more detail in 3.4.2, 4.2 b, and 5.4 a).
2. Simplicity of tasks and technology increases the chances of success. In this research, the PersonA functions are developed to help users adhere to the health program by simplifying the tasks they must perform. For example, automatic input from sensing technology to the personal gateway is simpler than paper-pencil or manual typing input. Another example is the wizard/guideline that helps users to explore the most important functions of this platform without having to memorize them.
3. In order to achieve the optimal result, the platform will trigger users when they are most open to persuasion by designing a system to give immediate feedback, reminders, and greetings at opportune moments according to user's preferences, health professional recommendations, or specific contextual information. An example of this feature is an audible feedback that can be personalized in terms of frequency of report and feedback data reported. Each individual usually has different preferred data and feedback frequency. This audible interface was also implemented because the real time feedback is also needed when the users perform PA (e.g., running) and it is difficult to view feedback on the

smartphone while moving. The screenshot showing how to set the audible interface is depicted in Figure 6-14 below.

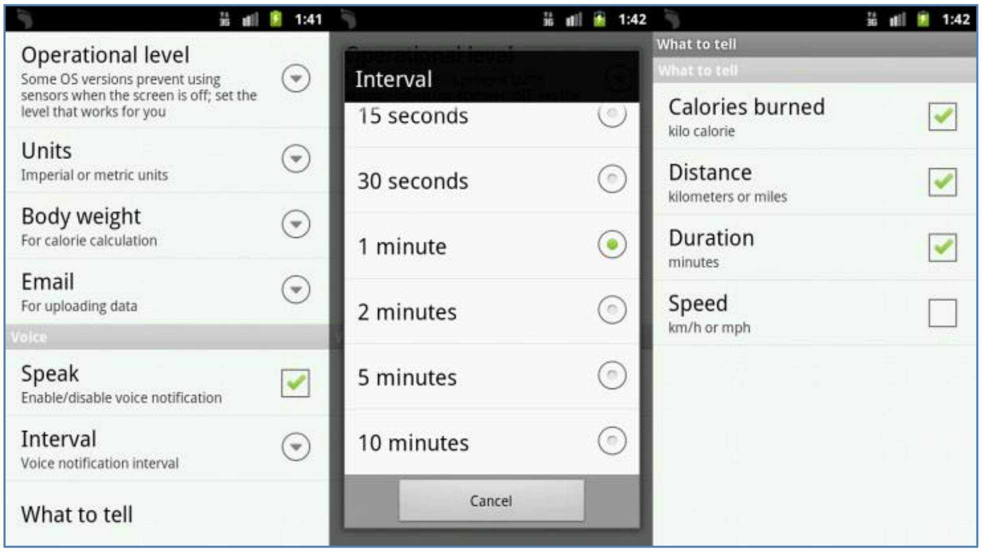

Figure 6-14. Audible Interface Setting

4. Interactive experiences that are easy to access and convenient have greater opportunity to persuade; therefore PersonA interfaces were built to be as interactive as possible. Two strategies were used to make PersonA interfaces interactive: a) the interactive experiences that are easy to access and convenient have a greater opportunity to persuade, and b) simplicity of tasks and technology increases the chances of success. Following the two strategies, the user interface of PersonA was developed to allow three themes (numeric, chart, and metaphor). The numeric theme is designed as a data dashboard which can help users to read data at a glance and which gives a better overall picture of the most important data. The chart theme is designed to give a better understanding and interpretation of information presented, especially by comparing the data over time, or comparing data among variables. Sometimes it also helps users to see long-term trends or individual dips and spikes. The metaphor theme was designed as data visualization by which the abstract structure of the data is mapped onto perceivable and interesting representations that,

hopefully, allow users to easily tease out interesting relationships or data structure. Moreover, the users who are familiar with the metaphor can easily interpret data at a glance. Two such metaphors are implemented in PersonA: aquarium and garden. These metaphors were chosen because they represent a positive reinforcement—the user is not punished for inactivity. Two relevant studies revealed that their subjects were very positive about the concept and confirmed that the display was understandable (Consolvo et al., 2008; J. J. Lin, et al., 2006). The idea behind these metaphors is: the more active the user is, and the higher their current status is compared to the target, the more complete and beautiful their aquarium or garden will be. For example, if the current PA status is between 60-80% of target, the users will have an almost complete aquarium or garden (Figure 6-16 and Figure 6-17). By giving this stratified interface based on PA performance, we expect that the users will be encouraged to perform better in PA, or at least, to have a more beautiful personal interface in PersonA.

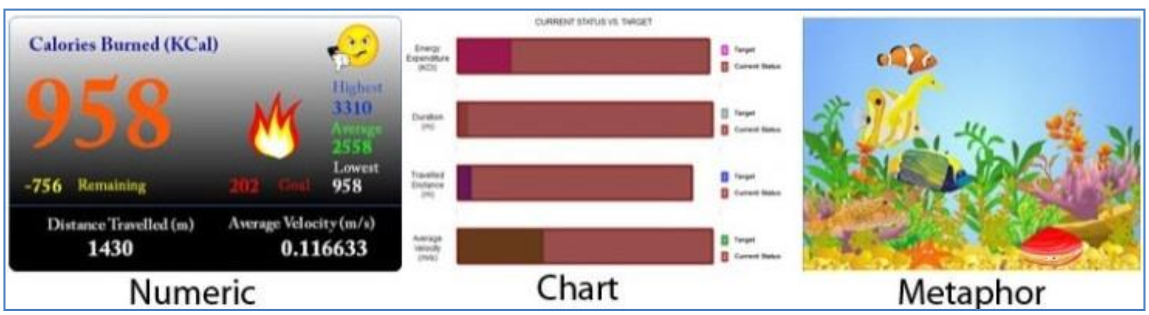

Figure 6-15. PersonA Themes of Data Visualization

Figure 6-16. Aquarium Metaphor

Figure 6-17. Garden Metaphor (Current > 80% Target)

All these themes are implemented in all data visualizations in this platform except visualization in the smartphone version of PersonA because of its limited screen size and computation power. The data visualization on smartphone uses only simple numeric and chart themes.

6.1.2.5 Facebook and Mobile Authentication and Authorization

Security and confidentiality in a health application is of paramount importance; thus we implement the following methods to ensure that the communication process is secure and confidential. First, the authentication process requires a combination of the device's phone number – International

Mobile Equipment Identity (IMEI) number, email address, and Facebook account. Only devices with proper and registered combinations are able to push data to and access information from PersonA. The web version of PersonA uses only a combination of email and Facebook account to authenticate users who want to access the information. Second, the communication platform of PersonA handles the encryption and authentication process. Third, the confidentiality setting of PersonA is inherited from the Facebook confidentiality settings. When users want to set up a public page for PersonA on their Facebook, the PersonA page will be public and vice versa; the confidentiality inheritance also happens when the users want to set the PersonA page as a private page. By default, the health data will be privately protected but summary data, such as maximum/minimum/average data, will be available for all members of the PA promotion group.

6.2 SYSTEM AS HEALTH INTERVENTION CASE AND PLATFORM IMPLEMENTATION

PersonA is designed to be a general platform that can work on many health-intervention and rehabilitation cases using self-management and social support as the main strategies. From a technological perspective, the difference between those cases would mainly be in the data collected, information presented, and data POI; however, the communication infrastructure and the interface for information presentation would remain the same for any type of case.

6.2.1 PAMS Sharing Unit

As the first leverage, PersonA platforms are implemented in one application called the PAMS Sharing Unit. The PAMS Sharing Unit is used to attract wheelchair users to increase their amount of PA per day in terms of energy expenditure. The PAMS Sharing Unit is part of a project called Physical Activity Monitoring and Sharing (PAMS) funded by the US Department of Defense (Grant number: #SC090323). The main purpose of the PAMS project is to develop a system that can capture physical activities that are part of the lifestyle in manual wheelchair users and can motivate them to be physically active via web-based or mobile social networking applications (Ding, et al., 2012). In the project, the subjects are manual wheelchair users (MWUs) with spinal cord injury (SCI).

The population from which subjects of PAMS project is drawn may experience physical inactivity. A. Buchholz, C. McGillivray, & C. F. Pencharz (2003) found that the PA levels of people with SCI are low and their daily energy expenditure (EE) is significantly lower than able-bodied ambulatory individuals. This study also revealed that only 13% of quadriplegic and 16.5% of paraplegic individuals in a sample of 170 university graduates reported being physically active and 30% of 596 individuals with SCI sampled across the U.S. did not exercise at all. Low levels of PA in this population have been associated with decreased aerobic capacity, muscular strength and endurance, and flexibility, all of which have the potential for restricting their functional independence and increasing their risks for chronic diseases and secondary complications (Fernhall, et al., 2008). In fact, this population reports a high number of chronic conditions e.g., diabetes mellitus and cardiovascular disease; and secondary complications e.g., fatigue, weight gain, pain, and depression (Bauman, 2006; Martin Ginis, et al., 2010; Tawashy, et al., 2009). At the same time, people with SCI face more barriers to participating in regular PA than the general population in addition to the barriers related to their physical limitations such as pain, lack of energy, and lack of accessible facilities and exercise equipment (Vissers et al., 2008).

Moreover, unlike the general population nowadays, which has access to a plethora of body monitoring devices ranging from simple pedometers to complex multi-sensor platforms that automatically track PA and provide feedback to increase user understanding and consciousness of their PA participation (Andre & Wolf, 2007), manual wheelchair users have no equivalent means to self-manage their PA participation. Only a few studies have looked into using activity monitors to measure physical activity among wheelchair users (Harris, Sprigle, Eve Sonenblum, & Maurer, 2010; Hayes et al., 2005; Tolerico et al., 2007; Washburn & Copay, 1999). These studies either measured time of travel and distances to indicate gross PA levels or examined correlations between wrist-worn accelerometer counts and energy expenditure of wheelchair users. None of them have provided a direct estimation of energy expenditure associated with physical activity or given real-time feedback to wheelchair users on their PA levels

Several studies have indicated that social influence from friends and family is an important determinant of PA participation in the wheelchair population. Warms, et al., (Warms, et al., 2007) investigated factors associated with self-reported PA among 50 manual wheelchair users. They found that social environment variables, including social support from family, friends, and healthcare providers, are more important than environment variables such as lack of transportation and facilities. Also these social variables were found to be of equal importance to the personal variables (e.g., age, self-efficacy, motivation, and depression) and to be more important than the health variables (e.g., BMI, pain, energy and fatigue, and self-rated health). Van den Berg-Emons, et al. (2008) identified that social influence from family and friends was the second strongest determinant of PA for people with physical disabilities one year after rehabilitation. Kerstin et al. (2006) conducted semi-structured interviews with 17 persons with SCI who were at least one year post-injury about factors that may promote participation in PA. They found that the ability to share with others and give support in the process of participating in PA strengthens one's own ability to participate in PA and also suggested that proper social support is sometimes considered a necessary condition for being physically active among the SCI population. In addition, a sports and employment survey conducted by the Disabled Sports USA found that the main sources of motivation for all 1108 adults with disabilities sampled, including 203 wounded warriors, were family members, doctors and friends (David & Orkis, 2009).

Due to the high prevalence of physical inactivity and its potential impact on health and secondary conditions; the increasing need for self-management practices; the increasing barriers to participating in regular PA; and the positive effects of social support among people with SCI, it is suitable and important to study this population as a target for health promotion efforts and intervention using a social network system, including health behavior promotion using the PersonA platform. The PAMS project also has intervention setting matched with this platform that implements the three concepts important to encouraging PA: self-management, social support, and persuasiveness.

The PAMS system consists of two parts: a monitoring unit and a sharing unit. As a monitoring unit, movement and energy expenditure sensors as sensing technology are attached to a user's body and wheelchair. These sensors are connected to an Android-based smartphone, and then are integrated to the sharing unit. The development and evaluation of the monitoring unit is covered by another study (Dan Ding's team at the Human Engineering Research Laboratories of Veteran Affairs of Pittsburgh, PA).

The monitoring unit of the PAMS integrates a wheel rotation monitor (WRM) clipped to the spokes of a wheelchair and an accelerometer-based monitor (i.e., wocket) worn around the dominant arm of the user (Figure 6-18). The WRM and wocket provide complementary information about physical activity in wheelchair users and allow more comprehensive and accurate assessment of multiple PA measures in this population. The WRM is a small, lightweight, and self-contained device that easily attaches to a wheelchair via two zip ties without any modification to the wheelchair. The WRM tracks the wheelchair motion by sensing the distance and velocity of the wheelchair user while in motion. The underlying technology is based on six reed switches and a magnet mounted at the bottom of a pendulum that detects wheel rotations and a gyroscope sensor that senses angular velocity. In addition, the WRM includes a Bluetooth module that wirelessly transmits the wheelchair motion information to an Android phone in real-time. The variables that can be obtained from the WRM are the total distance covered, average speed, and total wheelchair travel time. Further, we can also obtain information such as number of movement bouts and movement time at different speeds. The sampling rate for the WRM can be varied from 1Hz to 64Hz.

The wocket was developed by researchers at the Northeastern University as part of an open source effort to create very low-cost motion measurement devices for researchers in the field of activity monitoring (Intille, et al., 2011). Wockets are small, wireless 3-dimensional accelerometers that collect and wirelessly send data about body motion via Bluetooth in real time. The current sampling rate for the wocket is 40Hz. The phone also acts as personal gateway. C# RESTful web service, IIS 7.0 web-servers and SQL Server 2008 Enterprise Edition are used in the portal server. To access personal information and social interaction functions in Facebook, the Graph API 3 edition is used.

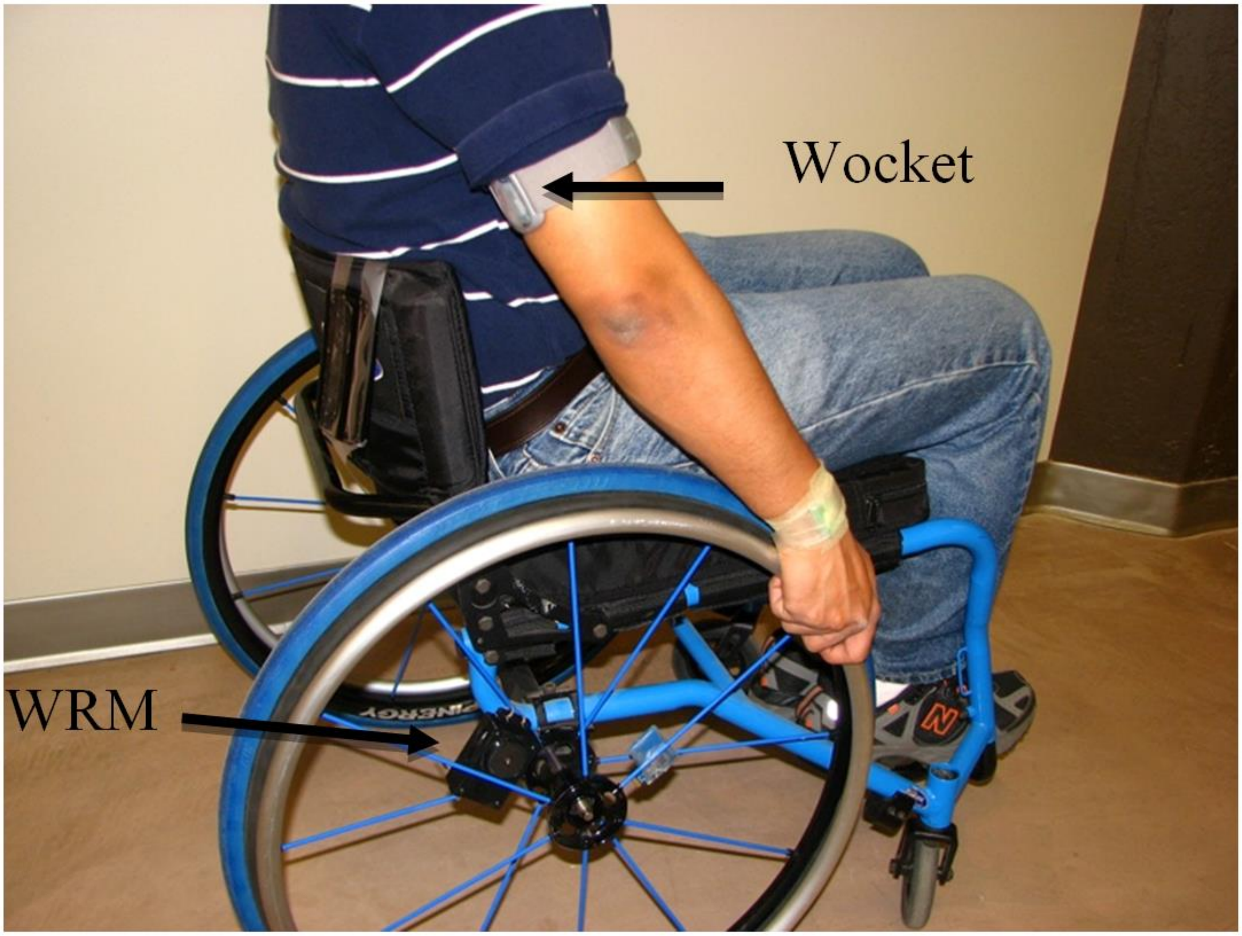

Figure 6-18. PAMS Monitoring Unit

This dissertation covers the development and evaluation of the PAMS system once the data readily available on the smartphone that include managing PA data and providing feedback to the users through the smartphone, portal, and social network system. The sharing unit of PAMS is implemented as part of the persuasive social networking system. A home display of the PAMS sharing unit is depicted in Figure 6-19

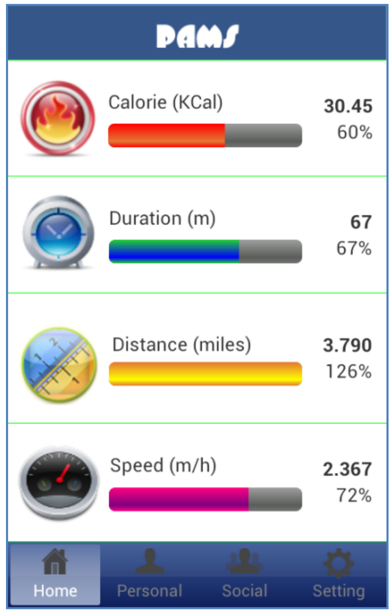

Figure 6-19. Home Screen of PAMS Sharing Unit

The correlation between the PAMS project and this dissertation is depicted in Figure 6-20 below.

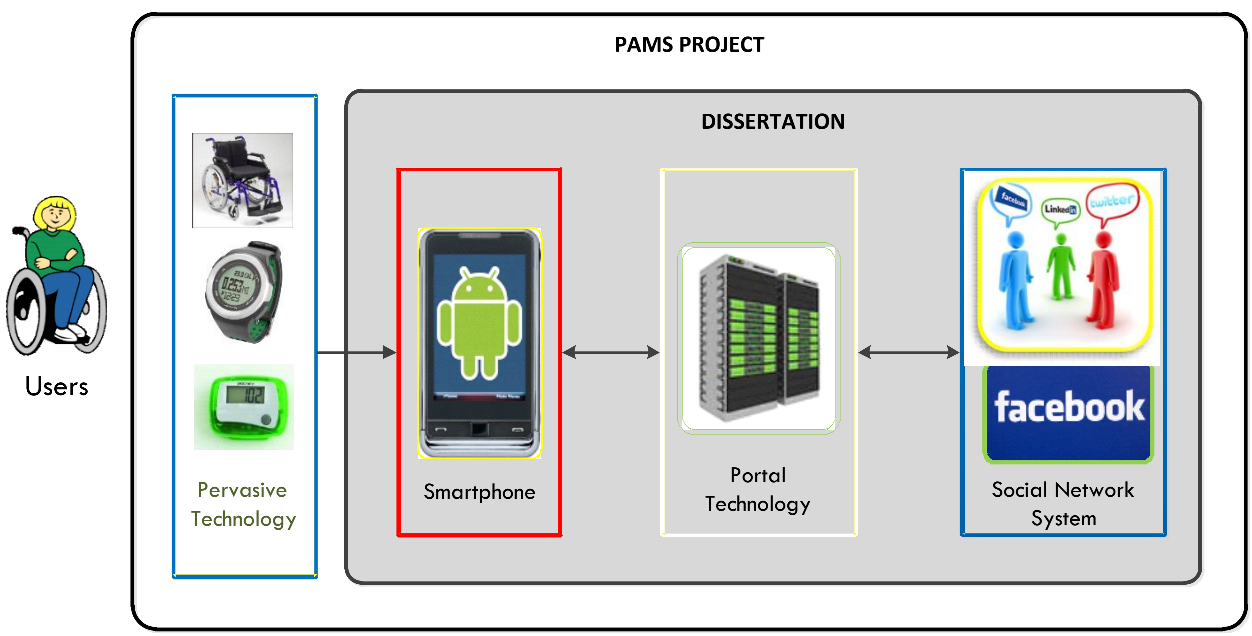

Figure 6-20. Correlation between the PAMS Project and the Dissertation

6.2.2 SocioPedometer

The second case that implements PersonA is the SocioPedometer project, where the system will be used to attract participants to have more physical activity in term of steps that they take every day. Considerable evidence has been accumulated to support the hypothesis that a moderate level of physical activity reduces the risks of coronary heart disease (Blair, et al., 1996; Thompson, 2003; Thompson, et al., 2007) and virtually all causes of mortality. Physical inactivity is also considered as a risk factor of hypertension and smoking (Fletcher, et al., 1992), stroke (Hu, et al., 2000), cancer (Verloop, et al., 2000), non-insulin dependent diabetes (Brancati, et al., 2000), and osteoporosis (Milgrom, et al., 2000). As a result, the Surgeon General (US Department of Health and Human Services, 1996) and Centers for Disease Control and Prevention (CDC) (Pate, et al., 1995) have developed guidelines to quantify the amount of physical activity required for health benefits. The guidelines state that, to maintain health, individuals with no known cardiovascular disease should accumulate at least 30 minutes of physical activity of at least moderate intensity for 5 or more days per week, or they should accumulate at least 20 minutes of vigorous-intensity aerobic physical activity 3 or more days per week. Despite the numerous benefits of physical activity and well-published exercise guidelines, only 38% of US adults engage in regular leisure-time physical activity and at least 25% were completely inactive in 2002-2004 (Adams & Schoenborn, 2006) and those numbers decreased to 30% engaging in regular leisure-time physical activity and at least 40% being completely inactive from 2005-2007 (Schoenborn & Adams, 2010). Furthermore, it has been shown that most individuals who do begin exercise programs do not continue (Castro & King, 2002).

Because the importance of PA and the lack of participation of those in the general population, great efforts have been made to develop methods to promote PA. One result of this effort is a guideline that is easily understood of “10,000 steps/day” to be the benchmark for an active lifestyle (Tudor-Locke & Bassett, 2004). The number of 10,000 was promoted at for the first time in Japan in 1965 by Yoshiro Hatano. However, the validity of this number is debated among experts, especially with respect to its relation to the target population, because it may fit a healthy young population but not be achievable for older people with mobility problems or people with chronic diseases; moreover, the target is too low for children and teens.

Apart from the debatable number, that number still led to the rapid development of a simple device called the pedometer. A pedometer is usually portable and electronic or electromechanical. It counts each step a person takes by detecting the motion of the person's hips. Used originally by sports and physical fitness enthusiasts, pedometers are now becoming popular as an everyday exercise measurer and motivator in health behavior programs. Direct and indirect evidence indicates that the Pedometer is effective as a tool to promote walking or running every day. For example, a study published in the Journal of The American Medical Association Nov. 2007 (Bravata, et al., 2007) concluded that the use of a pedometer is associated with significant increases in physical activity and significant decreases in body mass index and blood pressure. In addition to counting steps, it also provides users with some number of physical activity indicators such as distance travelled, duration, and energy expenditure. With the advanced development of portable devices, such counters are now being integrated into an increasing number of portable consumer electronic devices such as music players and mobile phones.

Given the well-documented effect of using a pedometer in promoting PA, the high prevalence of physical inactivity among Americans, an increasing need for self-management support tools and the positive effects of social support in physical activity, it is suitable and important to study general population as a target for health-behavior promotion efforts using PersonA systems.

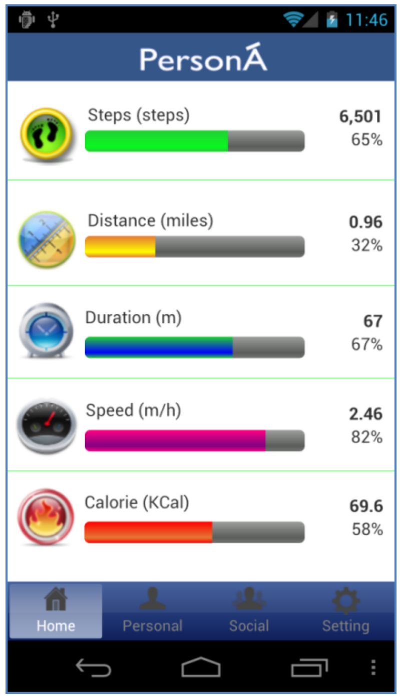

Figure 6-21. Home Screen of SocioPedometer

The internal accelerometer and gyroscope of an Android phone (Samsung Droid Charge) are used as the data point of input (POI) to implement the PersonA platform. Using acceleration data generated from the sensor and other parameters (weight and step length), the following PA data can be generated: steps, distance travelled, estimated energy expenditure, and average velocity. The phone also acts as personal gateway. C# RESTful web service, IIS 7.0 web-server and SQL Server 2008 Enterprise Edition are used in the portal server. To access the personal information and social interaction function in Facebook, the Graph API 3 edition is used.

7.0 USABILITY STUDY OF PAMS SHARING UNIT

In the development and evaluation phases, a group of potential users and clinicians guided the development and of evaluated the PAMS Sharing Unit to ensure that the requirements and features met with their needs. We worked with this group to determine which features are most useful; which features are most suitable in web apps, mobile apps, or both; what the pros and cons of those features are and how to mitigate the cons, what kind of interface is most effective/preferable, etc. The results of this evaluation were used to refine the system and to evaluate the model, framework, and platforms of PersonA (Described in detail in Chapter 9).

7.1 METHODS

7.1.1 Participants

The group that helped the researchers in the PAMS development phase included clinicians and five wheelchair users with SCI[33] (potential users). The inclusion criteria for subjects was 1) 18-65

[33] The human spinal cord is a bundle of nerve cells and fibers approximately 17 inches long that extends from the brain to the lower back. The spinal cord carries messages from the brain to all parts of the body and receives incoming messages from the body as well. When a person sustains an SCI, the communication between the brain and other parts of the body is disrupted, and messages no longer flow past the damaged area. The damage can occur at any level of

years of age; 2) using a manual wheelchair as a primary means of mobility (> 80% of their ambulation); and 3) having a diagnosis of SCI. The exclusion criteria include 1) unable to tolerate sitting for 2 hours; 2) having active pelvic or thigh wounds; and 3) having a history of cardiovascular disease (See Appendix A). All five subjects, all male, completed the study. Based on their self-reporting, they ranged in age from 27 to 53 (mean = 34.4, SD = 10.7). Their BMI ranged from 18.01 to 34.43 (mean = 23.56, SD = 6.51) with 1 of them considered obese according to Body Mass Index calculations performed using height and weight. They have used a manual wheelchair for 7-18 years with varied brands (make). Three of them have a complete SCI and two have an incomplete injury with varying SCI levels. Four of them are athletes with regular and good levels of physical activity. Two of them have 2-3 years experiences with a smartphone. Four of them are familiar with SNS while most of them have been using the SNS for between1 and 3 years, with frequency of access more than once a day, average use 1-8 hours per day, more than 200 online contacts, and membership in more than 10 groups. Detailed characteristics of the participants are presented in Table 7-1.

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the spinal cord, and the level of the injury will dictate which bodily functions are altered or lost. SCI levels can range widely, aligning with the condition of the spinal cord.

Table 7-1. PAMS' Participant Characteristics

Demographic Data	PARTICIPANTS				
	PA01	PA02	PA03	PA04	PA05
Gender	Male	Male	Male	Male	Male
Age	29	53	27	29	34
Body Weight (lbs.)	219	240	120	115	185
Height (inches)	80	70	66	67	77
BMI	24.06	34.43	19.37	18.01	21.94
SCI Level	T-8	C2-C7 T1-L4	L2-L3	T3-T4	C5
Completeness of Injury	Complete	Incomplete	Complete	Complete	Incomplete
Date of Injury Onset	1/13/2001	9/13/2004	8/12/1994	2/6/1999	9/17/2005
Ethnic Origin	Caucasian	Caucasian	Caucasian	African American	Caucasian
Manual Wheelchair Make (Brand)	Action/Invacare	Sunrise/Quickie	Sunrise/Quickie	Action/Invacare	TiLite/TiSport
Manual Wheelchair Model	Terminator Titanium		Titanium		ZR
Diameter of Wheelchair's wheel (Inches)	25		24		23
Start using manual wheelchair	1/13/2001	4/25/2005	8/12/1994	5/1/1999	10/2/2005
Dominant hand	Right	Right	Right	Right	Right
Athlete	No	Yes	Yes	Yes	Yes
Smoking	No	No	No	Yes	Yes

Table 7-1. PAMS' Participant Characteristics

(continued)

Demographic Data	PARTICIPANTS				
	PA01	PA02	PA03	PA04	PA05
Exercise habits	Occasionally (less than once a week)	Regular PA (weightlifting twice a we[illegible] three times a week)	Regular PA (weightlifting 3-4 [illegible] hockey 2-3 times a week)	Every day (Push up)	Regular PA (theraband three times a week, wrist cuffs three times a week, rugby once a week)
Follow specific dietary intake plan	Yes	No	No	No	No
Nutritional habits	Very good	Good	Very good	Fair	Very good
Fitness Level	Very good	Good	Very good	Good	Good
Education	Master degree	Associate degree	Bachelor		Vocational/Technical School
SNS Experience	Having SNS account for more than 3 years with average access of less than an hour per day	Having SNS account for 1-2 years with average access of 2-4 hours per day	Having SNS account for 1-2 years with average access of 1-2 hours per day	None	Having SNS accounts for more than 3 years with average access of more than 8 hours per day
Number of Online Contacts	>200	>200	100-200	0	>200
Number of Online Groups	>10	>10	0	0	>20
Smartphone Experience	None	None	Having IPhone for 2-3 years	None	Having IPhone for 2-3 years

7.1.2 Procedure and Study Design

The group evaluated the usability and persuasiveness of PAMS at the end of the development phase (July-August 2012). All subjects were asked to evaluate the PAMS prototype on a computer and smartphone by performing pre-defined tasks. In order to simplify the use of the PersonA, all of the tools they used for evaluation such as paper-based tools, computers, and smartphones were provided at test time. Each visit was completed within 2.5 hours. Before testing, the purpose and overall procedures of the study were explained to the subjects and informed consent was given (See Appendix A). At the beginning of the study, subjects were asked to complete two questionnaires to elicit demographic information and information about their use of Internet, smartphones, and social networking sites.

Once the pre-defined tasks were carried out, the participants were then asked to complete a usability questionnaire and were interviewed regarding the usefulness of the PAMS Sharing Unit. The interview explored what the users thought about the system design and about features above and beyond those implemented in the PAMS system including, but not limited to, general features designed to persuade users to perform healthier behavior. For example, the users were asked what the best way to deliver reminders to perform physical activity would be and which features should be implemented on mobile phone, web, or both. The interview was recorded so that it could later be transcribed for further data analysis.

7.1.3 Outcome Measure

In the PAMS study, usability evaluation was conducted using standard usability protocols: think-aloud, post-study questionnaires and semi-structured interviews (See 2.4 Usability).

7.1.4 Data Analysis and Sample Size Consideration

Following the standard data analysis for usability study (See 2.4 Usability), descriptive statistics were used to analyze the quantitative data obtained from the first and second protocols (think-aloud and questionnaire). The quantitative data includes success rates of each task, error rates, and satisfaction questionnaire ratings. All statistical analyses were preceded by a detailed descriptive analysis of the data using standard descriptive summaries (e.g., means, standard deviation, percentiles, and ranges) and graphical techniques (e.g., histograms, scatter plots). On the other hand, content and thematic analysis was used to analyze the qualitative data obtained in the third method (in-depth semi-structured interview).

As the evaluations of PAMS Sharing Unit is a usability study to serve as formative evaluation, based on the sample size consideration described in 2.4 Usability , a five participant is sufficient to detect usability problems for PAMS Sharing Unit study.

7.2 RESULTS

Five subjects completed the usability study of the PAMS Sharing Unit. Quantitative measures from this usability result are presented first, followed by results from the qualitative data in the form of a thematic analysis. Due to the nature of this study, all quantitative data will be analyzed mainly descriptively rather than by hypothesis testing. Overall, participants gave high scores for almost all usability factors of the PAMS Sharing Unit, with an average of 3.91 and 4.67 of 5.00 (maximum) for mobile apps and web apps, respectively. A detailed number for each component is summarized in Table 7-2.

Table 7-2. Usability Score of PAMS Sharing Unit

Usability Factors (1=totally disagree, 5 =totally agree)	Mobile Apps Mean (Standard Deviation)	Web Apps Mean (Standard Deviation)
It was easy to learn how to use this system	4.00 (1.22)	3.60 (1.14)
It was easy and simple to use this system	3.80 (1.30)	3.40 (1.14)
It was easy to obtain what I need	4.00 (0.71)	3.40 (1.14)
The interface of this system is pleasant	4.20 (0.84)	4.00 (1.00)
I like the interface of this system	4.00 (0.71)	3.80 (1.09)
The organization of information was clear	4.20 (1.30)	3.60 (1.14)
It was easy to navigate where to find what I need	3.80 (1.01)	3.60 (1.14)
Whenever I made a mistake using the system, I could recover easily and quickly	3.80 (1.64)	3.40 (1.14)
The system gave error messages that clearly told me how to fix problems	3.80 (0.84)	3.60 (1.14)
This system has all the functions and capabilities I expect it to have	3.60 (1.14)	3.80 (0.83)
Overall, I am satisfied with the quality of service/information being provided via this system	3.80 (0.84)	4.20 (0.45)
Average	**3.91**	**3.67**

7.3 DISCUSSION AND CONCLUSION

The PersonA platform was successfully implemented in an application called the PAMS Sharing Unit. The system was specifically designed to automatically record PA and to encourage users to have more PA. Thus, at the end of the development phase, a typical usability study was conducted aimed at finding out whether the system is usable, accessible, and accepted by users. The specific aspects of usability and acceptability evaluated include: learnability, efficiency, error recovery, and subjective satisfaction. In the PAMS study, overall, subjects gave a considerably high score for each component, with an average of 3.91 and 3.67 out of a 5.00 maximum for mobile version and web version, respectively (See section 7.2). In summary, with the small sample size of this pilot study, and no other apps as comparisons tested directly, the usability results suggest that both systems are usable and accessible and that users were satisfied and enjoyed using the systems.

The study also identified a number of additional features or adjustments to be made, suggested by the participants. Those include a suggestion to increase the size of some of buttons in PAMS. This suggestion came from those who have difficulty using a smartphone because of high levels of SCI (C-1 and higher). Unfortunately, this suggestion cannot be directly applied because of the limited size of a smartphone screen and the fact that some of the buttons are natively sized by the Android operating system or the smartphone itself (e.g., keyboard size). Another limitation of the PAMS Sharing Unit identified in this study is a limitation related to battery specification. With the current specification, the PAMS Sharing Unit is only able to run about 6 hours to communicate with the PAMS Monitoring Unit because of the limited battery capacity in the PAMS Sharing Unit. However, in an ideal placement, which is also the purpose of this study, the system should be able to record daily life PA, including walking or propelling wheelchair that is not intended as formal physical activity or exercise.

Indeed, the usability results should also be interpreted cautiously because of the study limitations: sample size and characteristics, no other apps as a comparison, and outcome measure. To examine the usability, the sample size appears appropriate because usability testing to serve formative evaluation, like this study, usually uses The Problem Discovery Rate Model to determine sample size (J. R. Lewis, 1993b; Nielsen & Landauer, 1993; Virzi, 1992). This model gives fairly good estimation that 85% of usability problems will be revealed using five participants and almost 100% of problem using 14 participants (J. R. Lewis, 2006; Nielsen, 2000; Turner, et al., 2006). Nonetheless, the number seems to be less appropriate when compared against the wide range of SCI levels possible, from L5 to C1 (25 levels). The levels are not considerably represented in this sample.

Additional research is needed to determine whether findings extend to more heterogeneous users with varying levels of SCI and of activity (athlete or not). Given that three of participants have complete injury and two have incomplete injury with varied but not representative SCI levels, an extended research with those who have representative SCI levels is required.

A study to compare the PAMS Sharing Unit, even with a manual tool if the automatic tool is not available, should be conducted to give higher validity to the PAMS usability score. A comparison is still needed although participants gave high usability scores (See Table 7-2) and good comments represented by the following comments:

> *"Definitely on first glance, I think it's a lot more intuitive and usable than maybe what I thought. I know and I see a lot of time whenever complete studies here, what I see is bunch of number or line of chart on the computer but it's not easy to understand. But here, this apps gives me more meaningful information because of the format and the interface and the number that people familiar with. So, I think on the first glace, it's pretty usable and easy to use and I think if people are more comfortable using it, there are gonna more likely to use it. Even though with this limited screen size, it seems pretty easy to use, even I got pretty big fingers."* [PA01]

> *"The buttons are too small. But that's fine because if I have to use it all the time, I will use the pen or something else [stylus]."* [PA02]

Unfortunately, as far as their knowledge, there is no such system that is specifically designed to record PA performance of wheelchair users. The comments include the following ones:

"[I only use] Just my sense of how I feel and how my accomplishment for the day [to measure PA]. I just basically do self-feeling and self-study; I only guess what's going [with my physical activity] on the certain days. It [PersonA sharing unit] gives better idea what's your doing." [PA02]

"I don't really use any those technologies. I'm an athlete so I know what I'm doing. I keep track my activity even the calorie that I burned. But definitely if such things exist out there, I will use it. It should give me more idea about what I'm doing exactly." [PA03]

More exploration should also be conducted in regard to participants' experience with smartphones and SNS. With their physical limitations, participants expressed preferring to use the mobile version than web version as represented in the following comments:

"I think it just depends on where I am and what I am doing. I probably say choose the mobile one just because if you're out moving around and active and not bringing computer with you so you won't be able to check your data frequently. Yes, I think I'll choose the mobile one because it's easy to check the stuff." [PA01] (The participant has no smartphone but uses an IPad frequently.)

"I like the mobile little bit more; that's one I'm gonna use. It's less complicated yet complete." [PA02]

"I prefer the smartphone because I never really used computer anymore since I have a smartphone. I don't use Facebook; that's why at the beginning the smartphone version was a little bit confusing for me but eventually it's not hard to use. It's just a matter of a time to use it more frequently and should be more familiar with that." [PA03]

Even though a study to evaluate whether the system is acceptable and feasible to implement in daily life has never been conducted, participants gave various positive comments about the plan to deploy the system in their daily life. Typical comments include the following:

"That's not gonna hurt me; so, definitely I will get something plus." [PA02]

"I don't see myself posting that information; I'm not much of a poster. I'm not posting frequently but I really love to watch what other people are doing. Human nature for people wants to know what other people are doing; definitely they end up at least thinking and some other translating it into actions." [PA01]

Research is also needed to explore the role of SNS in general, and PAMS Sharing Unit in more specific detail, to extend the interaction in a support group that they already have right now.

The real support group combined with the PAMS may allow for better and stronger effects in promoting PA in this population. This is suggested by the following comment:

> *"It [PAMS Sharing Unit] could be good but I don't think that would be the same. In the support group, you sit in circle and indeed you sometimes need to meet people face to face, hold on hands, or just laugh together. But, yes, this kind of technology could be an alternative if you can't have that face-to-face one. Well it could help motivating if you have the support group and everybody there has this technology."* [PA02] (The participant was previously a mentor for newer injured people in a support group in one hospital in Pittsburgh, PA but in the last 3 years have not been active because of he is busy with the school activities.)

8.0 USABILITY AND FEASIBILITY STUDY OF SOCIOPEDOMETER

This chapter reports the results of a usability and feasibility study of SocioPedometer. The study serves several purposes, mainly viewed from the technological perspective: to find out whether SocioPedometer is usable, reliable, accepted by users, and persuasive; to find out how comprehensive data that can be collected; to evaluate whether all research protocols and tools are comprehensive and appropriate; to determine acceptability of the intervention; to reveal other technology deployment issues to prepare for bigger and clinical trials. In line with these purposes, the rest of this chapter is organized as follows. Section 8.1 explores the study design and method of this study including user scenario, participant characteristics, study design and procedure, and outcome measures. Section 8.2 details the study results for both the quantitative and the qualitative data. Section 8.3 ends this chapter with the discussion, conclusion, limitations of the study, and possible future work.

8.1 METHODS

8.1.1 User Scenario

In a typical user scenario, participants carry an Android smartphone loaded with the SocioPedometer application with them throughout the day. In the early morning every day, every Monday, and the first day of every month, users are asked to set a daily goal, weekly goal, and monthly goal, respectively. After setting up the goal, the users put the phone in their pocket or armband, and the SocioPedometer application automatically detects and counts every step that they take, calories burned, distance traveled, duration of PA, and average velocity.

8.1.2 Participants

To evaluate the usability and feasibility of SocioPedometer, fourteen potential users were recruited through online advertisement. Subjects were included if they were 1) 18-65 years of age; 2) able to operate computer and smartphone; and 3) able to walk or run without difficulty. The exclusion criteria were 1) inability to tolerate sitting for 2 hours or more; 2) a history of cardiovascular disease; and 3) history of breathing problems and/or respiratory disease with associated breathing problems. Thirteen subjects, 10 of them women, completed the study; one participant was excluded from the study and analysis for not following the study's protocol. Age of the participants ranged from 24 to 45 (mean = 33.1, standard deviation (SD) = 5.6). BMI ranged from 18.5 to 42.98 (mean = 26.8, SD = 6.6). Two subjects were overweight and four were obese. Half of them had prior smartphone experience, and all were familiar with SNS. Most of them had been using the SNS for more than 2 years with a frequency of access of more than once a day, with average use of one hour or more per day, with online contacts numbering more than 200, and with membership in more than 10 groups. Detailed demographic data is provided in Table 8-1.

Table 8-1. General demographic, fitness habit, smartphone experience, and SNS experience information

Participant	Gender	Age	BMI	PA Habit	Smartphone Experience	SNS Experience
P01	Female	33	23.3	Jogging once a week and exercise intended walking 2-3 times a week	No experience	Several times a day, for more than 3 years
P02	Female	40	30.1	None	No experience	Several times a day, for 2-3 years
P03	Female	32	22.5	Occasionally	No experience	Several times a day, for more than 3 years
P04	Female	35	42.9	Occasionally	less than 1 year	Several times a day, for more than 3 years
P05	Female	25	30.1	Twice a week (jogging, cycling, rowing, and strength training)	No experience with smartphone	Several times a day, for more than 3 years
P06	Female	24	34.6	None	No experience	Once a day, for more than 3 years
P07	Female	45	22.3	3-4 times a week (treadmill, elliptical, zumba/latin heat, weight lifting)	1-2 years	Several times a day, for 2-3 years
P08	Female	30	21.3	2-3 times a week tennis and jogging; 5 times a week stretches	1-2 years	Regularly log on, for more than 3 years
P09	Female	31	18.6	3 times a week jogging	No experience	Regularly log on, for more than 3 years
P10	Female	30	26.8	Walking once a week, jogging once in two weeks	1-2 years	several times a day, for 2-3 years
P11	Male	34	24.2	Once a week running and swimming	2-3 years	Regularly log on, for more than 3 years
P12	Male	29	26.6	Twice a week running	More than 3 years	Regularly log on, for more than 3 years
P13	Male	30	24.1	2 times a week running and tennis, and 3 times a week swimming	6 months - 1 year	Several times a day, for 2-3 years

8.1.3 Study Design and Procedure

This study was approved by the University of Pittsburgh Institutional Review Board (IRB PRO12020634) (See Appendix B). Subjects started participation at the end of the SocioPedometer development phase (May-June 2012). Participants were invited to two 2-hour visits at the University of Pittsburgh. During the first visit, the purpose and overall procedures of the study were explained. After signing a consent form, participants were asked to complete two questionnaires eliciting demographic information and information about experience with the Internet, smart phones, and social networking sites. Then, a brief orientation and demonstration on how to use SocioPedometer were provided. After the orientation, subjects were sent home and asked to use SocioPedometer daily for four weeks. A smartphone with an unlimited data plan was provided to each subject. During the four-week period study, the built-in tracking function in SocioPedometer was active to monitor all activities done by users with SocioPedometer, determining how much time participants spent using the application, how often they used the application, and which features of the application they used. To build a baseline of personal PA, the participants had no social interaction (social menu) in the first week; the social menu was introduced in the beginning of the second week and was available until the end of the study.

At the end of fourth week, the subjects were asked to come back to perform a number of tasks using a think-aloud method, then asked to complete a customized usability questionnaire (See Appendix C). Another questionnaire designed to evaluate the persuasiveness of SocioPedometer was then given to the participants. At the end of this process, subjects were then asked to participate in an in-depth semi-structured interview. The interview served three purposes. First, it was to clarify participants' answers on the usability questionnaire, if needed. Second, it explored what the users thought about the system design and features of a mobile application for PA promotion, including features beyond those already implemented in the SocioPedometer. Third, it answers several questions related to the feasibility evaluation especially those related to participants' experience during the study period. This interview was video recorded for transcription and further data analysis.

8.1.4 Outcome Measures

1. Usability

In the SocioPedometer study, usability evaluation was conducted using standard usability protocols: think-aloud, post-study questionnaires and semi-structured interviews (See 2.4 Usability).

2. Feasibility

The feasibility information was obtained through the semi-structured interview or the embedded function tracking user activities with SocioPedometer. No existing standard measurement tools or methods were used to obtain this information. There are several aspects of feasibility that were evaluated in this study, including participants' adherence to the program, user-system interactions, and participants' preferences with regards to the systems, participants' motivation to use SocioPedometer, and participants' experience with PA and online social interactions.

3. Persuasiveness

A variety of data was intentionally collected in order to explore behavior change in this study. The tools used include questionnaire, interview, user-system interaction, and physical activity data. For example, one important factor of persuasiveness, changing behavioral stage, was gathered using a questionnaire. This questionnaire was based on the Transtheoritical Model (TTM) proposed firstly in 1977 by James Prochaska and colleagues (See 2.1.4). This model was used to compare the participant's behavioral stage before and after joining the study because change in behavioral stage is a significant sign of persuasiveness.

4. Pilot Physical Activity Data

Five sets of PA data were collected in this study: number of steps, energy expenditure, duration, distance traveled, and average velocity. Number of steps was obtained using the smartphone-based accelerometer sensors. These sensors were tested in a lab environment where researchers put the smartphone in their front pants pocket, walking (and mentally counting) 400 steps; this procedure was repeated 7 times. The sensors recorded a fairly accurate count in a flat area, with between 11-24 steps lost. Results may be less accurate in uncontrolled environments, during uncontrolled activities, or with uncontrolled movements in participants' everyday life. Energy expenditure data was estimated based on calculation of number of steps and body weight. Duration was calculated by determining if there was at least one step in a one minute period. If there is at least one step, one minute was added to the duration. Distance traveled was calculated based on multiplication of number of steps and step length. Average velocity was calculated based on number of steps, step length, and duration.

8.2 RESULTS

Thirteen subjects completed the study. Over 29 days, they used SocioPedometer to collect PA data for a total of 122,630 minutes (average = 5.42 hours/day/participant). For both usability and feasibility results, quantitative measures are presented first, followed by qualitative data in the form of a thematic analysis. Since this is a pilot study, all quantitative data will be analyzed mainly descriptively rather than by testing hypothesis.

8.2.1 Overall Usability

Overall, almost all of the usability factors were rated highly, with an average of 3.97 and 4.09 of 5.00 (maximum) for mobile apps and web apps, respectively; except for 'error recovery,' which is only rated of 3.00 and 3.40 for both mobile apps and web apps, respectively. A breakdown of the numbers for each factor asked about is presented in in Table 8-2.

Table 8-2. SocioPedometer Quantitative Results for Overall Usability

Usability Factors (1=totally disagree, 5 =totally agree)	Average (SD)
It was easy to learn how to use this system	4.42 (0.99)
It was easy and simple to use this system	4.33 (0.98)
It was easy to obtain what I need	4.17 (0.94)
The interface of this system is pleasant	4.00 (0.60)
I like the interface of this system	4.00 (0.60)
The organization of information was clear	4.08 (0.90)
It was easy to navigate to find what I need	4.08 (0.67)
Whenever I made a mistake using the system, I could recover easily and quickly	3.91 (1.08)
The system gave error messages that clearly told me how to fix problems	3.00 (1.20)
This system has all the functions and capabilities I expected it to have	3.67 (0.98)
Overall, I am satisfied with the quality of the service/information being provided via this system	4.00 (0.85)
Average	**3.97**

8.2.2 Accuracy, Usefulness, and Willingness to Use

Participants gave various scores for ‘accuracy’, overall usefulness, and willingness to use when the system is available. When asked to estimate the percentage of total steps actually captured daily by SocioPedometer (sometimes they did not have the phone with them), answers varied widely, as can be seen in Table 8-3.

Table 8-3. Perception of Accuracy

Accuracy Level	Number of Participants
Extremely accurate	0
Very accurate	4
Moderately accurate	7
Slightly accurate	2
Not accurate	0

When participants were asked what percentage of their total number of steps they estimate SocioPedometer can capture when they did not bring the phone, they reported various numbers. Table 8-4 shows specific responses.

Table 8-4. Percent of Steps Captured using SocioPedometer

Percent of Steps Captured	Number of Participants
> 80%	3
> 60% and <= 80%	7
> 40% and <= 60%	2
> 20% and <= 40%	1
< 20%	0

Most participants reported that the mobile version is very useful or extremely useful, with two participants reporting it being moderately useful. Lower scores were given to the web version. A detailed report of the usefulness factor responses is provided in Table 8-5.

Table 8-5. Number of Participants and Usefulness Matrix

Web Version	Mobile Version					
	Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	Not Useful	NA
Extremely Useful						
Very Useful	4	2				
Moderately Useful	2	1				
Slightly Useful		1	1			
Not Useful						
NA		2				

The same theme arises, a lower score given to the web version, when participants were asked whether they would use the system when it's available. Table 8-6 reports individual participants' answers.

Table 8-6. Number of Participants and Willingness to Use SocioPedometer when Available

Web Version	Mobile Version					
	Definitely use	Probably use	Not Sure	Probably not use	Definitely not use	NA
Definitely use	1	1				
Probably use		4				
Not sure	1	1	1			
Probably not use		3				
Definitely not use						
NA	1					

Although perceptions varied, participants thought that SocioPedometer was useful because it provides a good estimation. Typical comments included:

“The apps may not give a very accurate step counting, but it perfectly cues the estimation range. Several times I tried to count my steps manually by walking through one to two blocks, and matched it with PersonA. I put the smartphone in my bag most of the time (do we need to consider the way we hold our bag?? hand-hold bag, backpack, messenger sling, etc.). The result is pretty much tight, around 30-40 step difference, if I'm not mistaken. To me, it concludes that the apps work perfectly well. Even with some intervening variables that might count (such as how we hold/put in the phone in the bag, walking pace, and bag swings), the apps work well in providing an estimated range of actual steps.” [P01]

“Yes, it is [useful], because I am more interested in relative numbers than absolute numbers. I want to know if I walked more today than I did yesterday, which it can tell me even if the accuracy is low.” [P05]

“Good to know if it can be improved but is still useful with this current level accuracy.” [P07]

When asked in which way SocioPedometer is useful, participants recorded a variety of answers, shown below in Table 8-7.

Table 8-7. Number of Participants and Usefulness Factors in Mobile and Web Version

Usefulness Factors	# Participant for Mobile	# Participant for Web
Making new friends	0	0
Self-monitoring physical activity levels by comparing current and target level	12	10
Knowing the activity levels of others or aggregate of the group	6	7
Comparing your activity with others	6	8
Finding people to exercise together	3	4
Sharing experience with others	3	6
Supporting each other	5	7
Finding useful information about physical activities	1	2

8.2.3 Motivation to Use

Three themes of motivation to use the SocioPedometer emerged from the qualitative sampling of participant comments obtained from interviews conducted during the study. One motivation was wanting to know more about the number of steps that they make throughout a day, inside and outside the gym, especially for those having poor or fair daily PA levels. A typical response was:

> *"I wanted to know how the system works. It seems interesting. Well, another reason is [this term] I don't have any class, so since last two months I need and want to have more physical activity. Fortunately, you offer this opportunity; this machine which I think would be very helpful. For me the most important thing is the steps. The calories are important but I had bad experience, when I use [traditional] pedometer, I knew how many kilo calorie that I burned and then when I calculated my eating, it seems much bigger and it make me feel depressed."* [P02]

Another motivation for using SocioPedometer participants expressed was to balance calorie intake-outtake, especially for those having good or very good daily PA levels. Typical comments include:

> *"I was interested knowing my energy expenditure. I want to see how many calories that actually I got and burned. Even though I go to gym twice a week and see how many calories that I burned on the machine display, I was curious to see how many more calories that I burned outside the gym which lead me to more information about calories that I burned during the day. [Steps] doesn't really give me the information, I don't really care how many steps I have, I care whether my calorie intake-outtake is balanced or not."* [P05]

The last motivation that emerged was being curious about how social interaction influences PA habits:

"I'm curious about the social network aspect of the apps, because I'm familiar with such tracking devices as the treadmill, and those kinds of devices in the gym. After you mentioned about the social feature of your apps, I was curious to know whether it would change my perspective on exercise or not." [P03]

8.2.4 Suggestions for Improvement

Three themes arose when participants were asked for suggestions to improve SocioPedometer. The first theme involved including other types of PA:

"That would be nice if it includes other kind of activities, not just running and walking; like cycling and rowing." [P05]

The second theme is to resolve the battery problem:

"The battery is a big problem for me, especially when I have to go outside and I forget to bring my charger. It needs one hour to charge but then only last for 5 hours. – P06"

The last theme is to have smaller devices:

> *"If possible, I want smaller devices, instead of this bulky phone. It would be a lot easier for me to carry or put the small one in my pocket. [So that I can put it in my pocket when I'm] at home, and I can get a credit [for walking that I take at home]".* [P01]

8.2.5 Mobile vs. Web Version

A comparison to an old web version of SocioPedometer having features similar to the SocioPedometer mobile version was used to evaluate users' preference of web vs. mobile versions. When the participants were asked which version of SocioPedometer they prefer, all of them choose the mobile version; several typical comments include:

"I like the smartphone one because I'm more likely to see the data on smartphone, for example while waiting for the bus or even on the bus. When I access a computer, I have so many other things to do, like working, checking email, etc. I would forget to access the apps [on the web]." [P05]

"I like the smartphone version. It's easy to check, for example, while I'm walking or waiting for the bus. You just click it. I don't really need that [web version]. What I have [SocioPedometer] in my smartphone is more than enough. [P03]

"I prefer the mobile because I bring the phone whenever and wherever, not like [SocioPedometer on] Facebook [web]. Yes, I access the Facebook [web] but only several times and in very short duration. I don't have time to access the system [SocioPedometer on the web]. [P01]

8.2.6 Data Visualization

All SocioPedometer users found it very convenient and easy to understand the information in a progress chart. Typical comments include:

"I like the chart most because it's very easy to visualize how far my data from the target." [P05]

Other visualizations, such as Metaphor were seen as fun but not practical:

> *"I love the graph, it's very clear, very easy to understand, and it's very crisp! It's very easy to visualize how far me from my target. But when my daughter saw the aquarium and garden, she loved it. [But] it then gave a burden on me, [because] she asked me to do more walking, just to have more beautiful garden or aquarium. But overall, [aquarium and garden] is fun to see but not practical; unless you want to post them on the door so it will encourage you when you're going outside."* [P02]

8.2.7 Online Social Interaction

Participant responses with regards to online social interaction reveal that SocioPedometer may leverage online social interaction to improve PA in variety of ways and on different levels. The variety is represented in the comments listed in this section:

One participant stated that social interaction may not work for her or some other people:

> *"I have my own personal life, personal plan, and personal schedule, so I never compared and never wanted to be encouraged to do walking. I know that I need physical activity; I know 10,000 steps per day [guidelines]. I definitely will do it when I have time. In doing that, I feel happy, I feel better, and I feel good about doing [physical activity] based on my personal target. I can imagine that once I'm able to compare my data to other participants, I will be angry simply because I don't have enough time to do what they can do."* [P07]

A comparison tool in SocioPedometer, both comparing to a target or to others' performance, may increase motivation to do more PA in some participants. They also said that online social interaction indirectly encouraged them to do more PA by letting them know they have company:

> *"Comparing with my friends is really nice but I only use it to map myself in the groups. I don't really Facebook people. I don't like see the status, post status or comments, but it's so good to know that there are other people doing it, so I feel like not lonely while doing [physical activity]. I never compared my data personally to my friends. I have my own target. You know, I have my own schedule and my own plan; sometimes I'm very busy, even don't have much time for sleeping. Yes, sometimes it doesn't work, if I have to compare personally, I will be left behind and feel guilty. I don't want that."* [P02]

Even though that social interaction is mainly intended to provide social support, some participants see the benefits for their own personal motivation such as implied in the following note:

"Posting to Facebook is a really nice and fun feature. I posted a status and I got a comment from P03 and it was nice too. It's fun! It was really nice to share and got support informally. But, I only post the data on my own wall, because it's more like to tell myself that I have to work [on exercise] today. Yes, to remind myself." [P05]

Other participants recognized the significant positive effect of online social interaction in encouraging and improving PA level:

"Indeed, the social interaction in SocioPedometer changed my walking behavior. I still remember several months ago, when I wanted to meet friends in Pitts, I took the bus with total, including waiting time, around 30-40 minutes. I don't do it anymore since knowing that some of my friends having thousands steps more than me. If I want to meet those friends, I just walk… it turns out, I only need 20 minutes to walk. It makes me feel good because I'm as active as my friends. It saves my time and makes me feel healthy. It also changes the way I go to the school, I don't take bus anymore. I walk! Last Sunday, I wall from Sq. Hill to Oakland all the way just to have more walks than theirs, I never did before. It gives even stronger effects when somebody else sending you a message 'walk walk walk…!'" [P03]

8.2.8 TTM-Based Behavior Change

We evaluated the behavioral stages of participants in terms of TTM stages (See 8.1.4-2) before and after joining the study using a self-report questionnaire. Results are provided in Table 8-8.

Table 8-8. TTM-Based Behavioral Stages Changes

Participant	Before	After	Note
P01	Maintenance	Maintenance	More intense
P02	Preparation	Action	
P03	Contemplation	Action	
P04	Contemplation	Preparation	
P05	Preparation	Action	
P06	Pre-contemplation	Contemplation	
P07	Maintenance	Maintenance	More intense
P08	Action	Maintenance	
P09	Action	Maintenance	
P10	Preparation	Preparation	
P11	Maintenance	Maintenance	More intense
P12	Contemplation	Preparation	
P13	Maintenance	Maintenance	

8.2.9 User-System Interactions

The purpose of collecting use-system interaction data is to find which version and which features were used most. As Table 8-9 shows, it seems that accessing personal data is favored over social interaction.

Table 8-9. User-System Interaction per Week

Action	WEEK 1		2		3		4		Total		Grand Total
	Mobile	Web	Mobile	Web	Mobile	Web	Mobile	Web	Mobile	Web	
Accessing Home[1)]	1,046	23	1,194	14	1,025	17	1,563	7	4,828	61	4,889
Accessing Personal Data[2)]	548	6	889	5	683	2	526	10	2,646	23	2,669
Social Interaction[3)]	0	0	356	19	498	17	261	8	1,115	44	1,159
Accessing Goal or Change Goal[4)]	106	0	434	0	428	0	256	0	1,224	0	1,224
Application Setting[5)]	215	23	135	10	113	29	106	12	569	74	643

1. Accessing home: this represents how many times the participants accessed the home page of SocioPedometer. This number also represents the frequency of users' access to SocioPedometer because the home page is the first page loaded when accessing the apps.
2. Accessing personal data: this represents how many times the participants viewed personal PA information. The information is a comparison between actual performance and target in the selected day, one-day before, the current week, the current month, and total period since the participants began using the apps.
3. Social interaction: this represents how many times the participants did social interactions, which includes social comparison and social support. Social comparison includes sharing data with a friend, a member group, or even all friends on Facebook. It also includes equating their PA performance and target with those of others in the group, the group average, the larger community average, or the norm standard set by health practitioners. Social-support activities include giving rewards or greetings for reaching a goal, sharing experiences or activities, and "liking" others' status or data.
4. Accessing goal and change goal or target: this represents how many times users set up and review their daily, weekly, or monthly goals.
5. Application setting: this represents how many times users set up the application. It includes setting email, setting body weight, setting or changing sensitivity of the accelerometer sensor, setting or changing physical activity types (running or walking), and setting or changing theme (only in web version).

8.2.10 PA Data: Summary

As a summary, over the 29 days of the study, participants used SocioPedometer to collect PA data for an average of 6.98 hours/day/participant; 5,542 steps/day/participant; 1.38 miles/day/participant; and 119.14 KCal./day/participant.

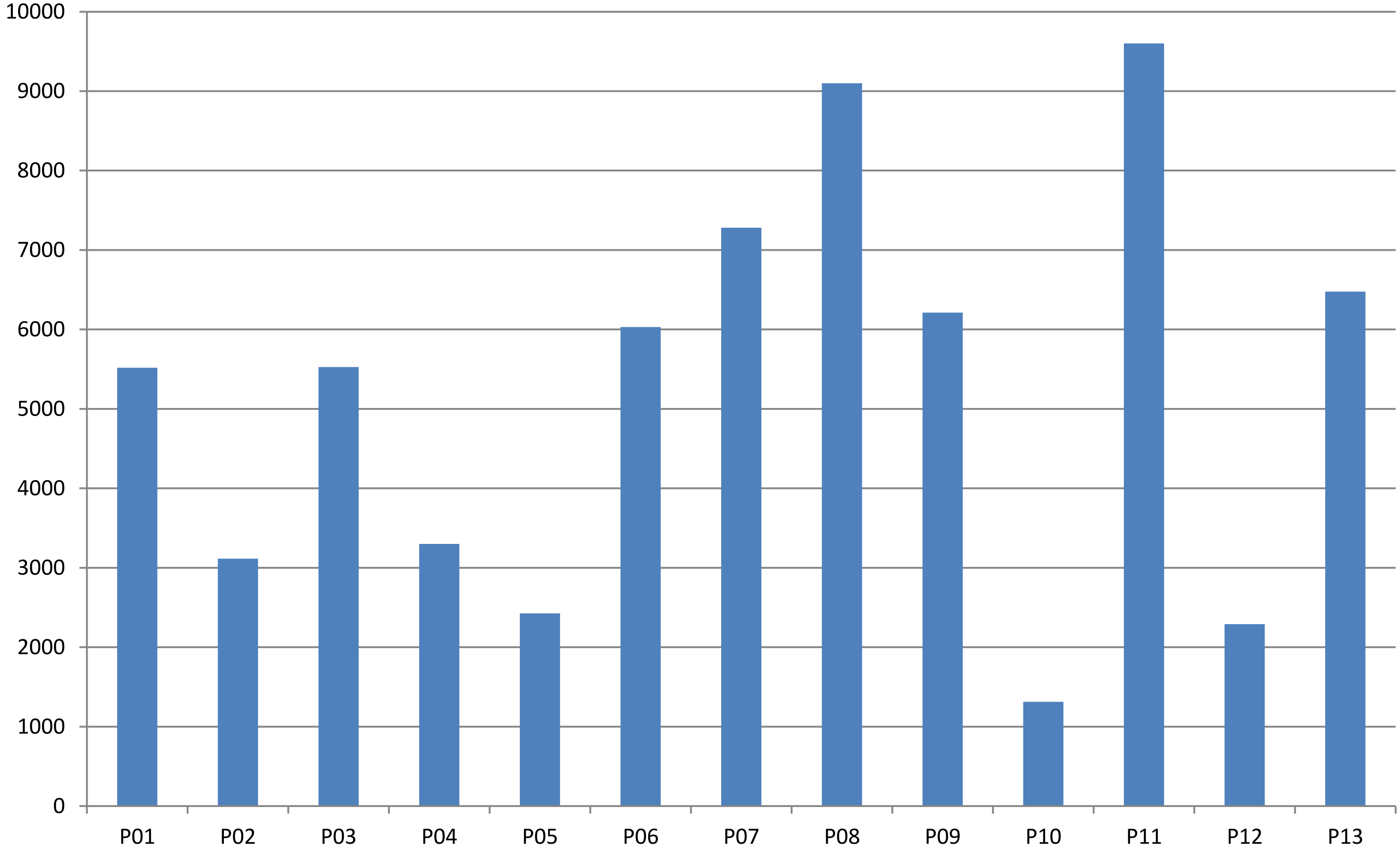

Figure 8-1. Average Steps / Day for Each Participant

8.2.11 PA Data: Comparison between "Without Social Features" and "With Social Features" periods.

An average of 1,598 steps difference was recorded on average steps per day per participant between the period of the first week and the rest of the weeks. The difference is statistically significant according to the result from "Dependent Paired T-Test Comparison"[34] (Figure 8-3). A detailed step comparison for all weeks is presented in Figure 8-2. Other PA comparisons are presented in Appendix D.

[34] "Dependent Paired T-Test Comparison" is used to compare one variable data from the samples that are dependent; that is, when there is only one sample that has been tested twice (repeated measures) or when there are two samples that have been matched or "paired".

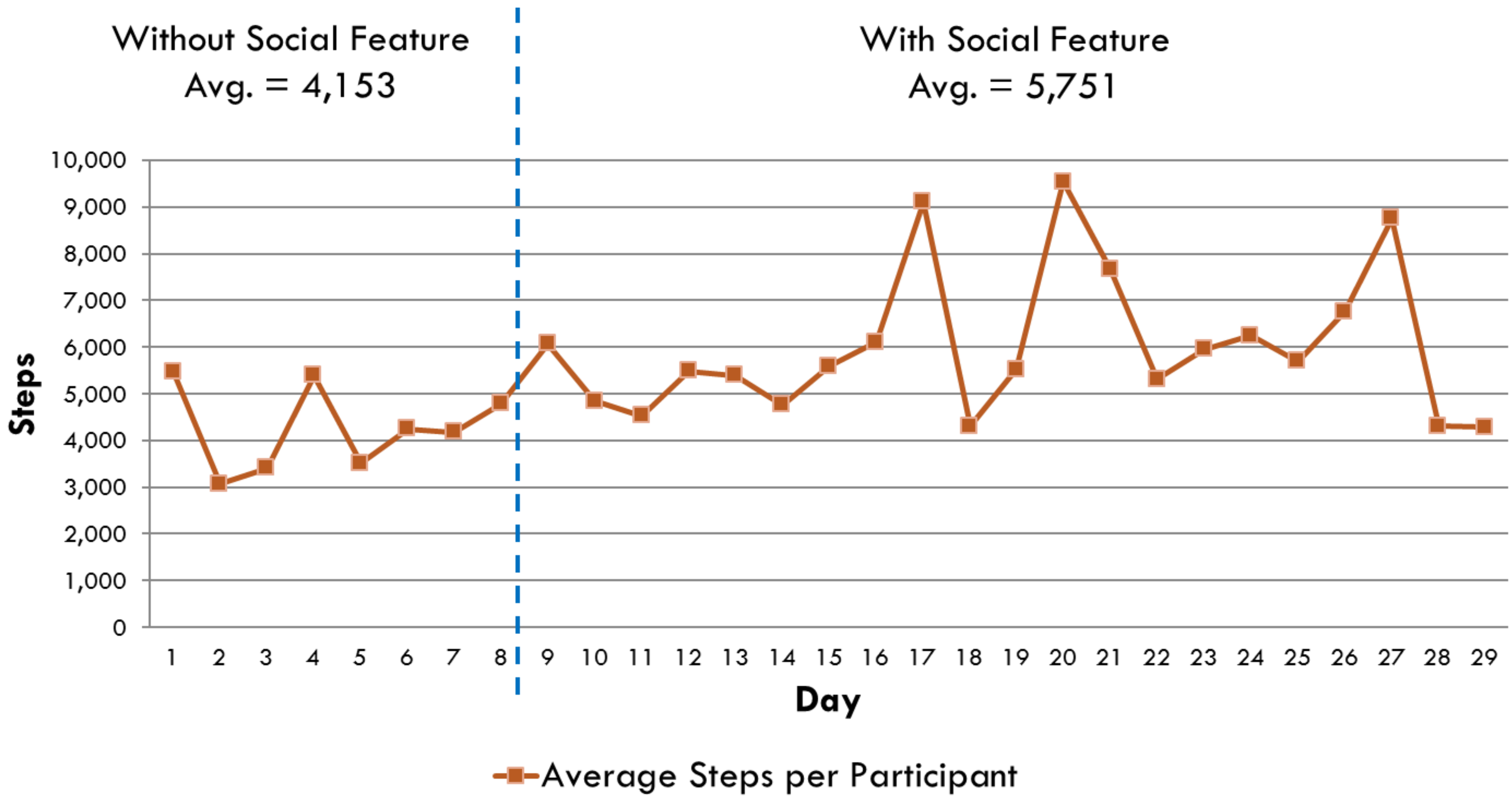

Figure 8-2. Steps Comparison between 'Without Social Feature' and 'With Social Feature'

Pair	Mean	N	Std. Deviation
Without Social Features	4,153.51	13	2,406.80
With Social Features	5,751.40	13	2,909.03

Pair	N	Correlation	Sig.
WITHOUT_SOCIAL_FEATURE & WITH_SOCIAL_FEATURE	13	0.774	0.002

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
WITHOUT_SOCIAL_FEATURE - WITH_SOCIAL_FEATURE	-1597.89	1847.83	512.49	-2714.52	-481.25	-3.11	12	.009

Figure 8-3 Dependent Paired T-Test Comparison between Steps Number Average on the First Week and the Rest of the Weeks

8.2.12 Social Interaction and Number of Steps

No trend is apparent in the relationship between the number of average steps/day/participant and social interaction (See Table 8-10). A bubble chart designed to plot the association between the time, average steps/day/participant, and average social interaction/day/participant is shown in Figure 8-4.

Table 8-10. Social Interaction and Step Number

Week	Average Social Interaction/ Day/ Participant	Average Steps/ Day/ Participant
1	0.00	4,199
2	53.57	5,137
3	73.57	6,736
4	38.43	5,928

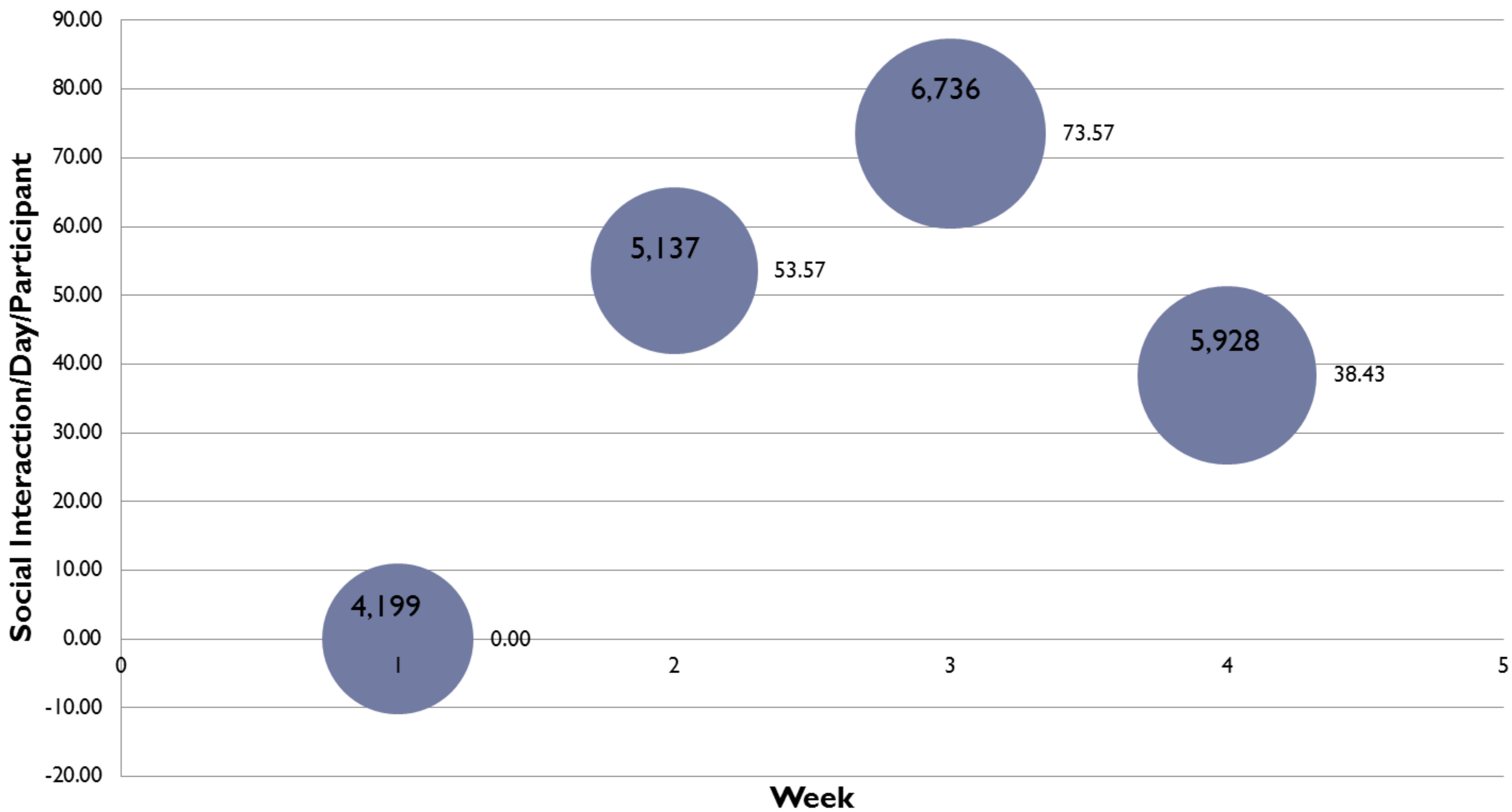

Figure 8-4 Duration, Social Interaction, and Number of Steps

8.3 DISCUSSION AND CONCLUSION

The overall goal of this research was to develop a system that can automatically measure PA level and encourage users to engage in more PA. A typical usability study was conducted to find out whether the system —SocioPedometer— is usable, accessible, and accepted by users. Overall, subjects gave a high score to each factor of usability (i.e. learnability, efficiency, error recovery, and subjective satisfaction) with an average of 3.97 and 4.09 of 5.00 (maximum) for mobile apps and web apps, respectively; excluding the value for 'error recovery' which was only 3.00 and 3.40 for mobile apps and web apps, respectively (See Table 8-2). Even with the small sample size of this pilot study and no other apps as comparisons tested directly, the usability results suggest that the system is usable and accessible, and users were satisfied and enjoyed using it.

We also examined the feasibility of using SocioPedometer for daily life PA promotion. The specific purposes of the feasibility evaluation were to explore users' experience with the system, to determine the acceptability of the interventions and protocols, to find out how comprehensive the data collected could be, and to reveal other technology deployment issues to prepare for bigger and clinical trials. Quantitative analysis of the results of this study showed positive results. The dropout rate of this study was 7% (1 of 14), which is in the average range of 4% to 16% dropout rates reported by a meta-analysis of PA interventions (Hillsdon, Foster, & Thorogood, 2005) and is better than the 20% of that of another meta-analysis (Bravata, et al., 2007). With regards to adherence, participants used the system to record PA for an average of 325 minutes (5.42 hours) per day and they accessed various system features 28 times per day on average (See Table 8-9). These numbers are high when compared with use numbers from a survey conducted by the Consumer Health Information Corporation. This survey found that smartphone applications have a high rate of dropout, with 26% being used only once and 74% being discontinued by the 10th use (McLean, 2011). The high usability scores and the high frequency of use and the usefulness scores indicate that participants not only liked the design of the application, but also found it convenient and useful and so used it frequently. It has been established that for a user to adopt and frequently use a smartphone application in long term, the user must consider it both usable and useful (Verkasalo, López-Nicolás, Molina-Castillo, & Bouwman, 2010). Therefore, our positive numbers indicate that users are likely to continue to use it. This is consistent with a consideration of that lack of usability and usefulness are top reasons for users to discontinue smartphone application usage (McLean, 2011).

Qualitative analysis highlighted the acceptability of different parts of the intervention and its protocol. For example, although participants gave varying scores for accuracy, most of them thought that SocioPedometer was moderately accurate in counting steps and most of them estimated that SocioPedometer recorded between 60% and 80% of their total actual steps throughout a day. They also commented that it is useful for their daily life because they can use the number as a relative number. Various typical comments supporting this statement are presented in the section 8.2.2. Furthermore, when asked in which way SocioPedometer is useful, participants gave a variety of answers, including it helped them to self-monitor their PA levels and to compare their performance with that of others, it facilitated the sharing experience, and it enabled them to support each other. Thus, most of them answered that they were willing to use SocioPedometer if the system became available in the future (See section 8.2.2). Thematic analysis of the qualitative data also indicates that SocioPedometer acted as a virtual coach, motivating half of the participants to be physically more active. This is consistent with a study finding that coaching the subjects to monitor behavior is an effective method of behavior change (Elder, Ayala, & Harris, 1999). Moreover, from the participants' perspective, it appears the combination of self-management practices and social support may act synergistically to keep some of them working toward their goals to have more active life style. New areas of inquiry were also identified during qualitative analysis, including the need to refine sources of motivation (See section 8.2.3); to explore emergent health behaviors in response to smartphone-based health applications such as users' preference of mobile over web version, if both are available (See section 8.2.5); and to explore users' preferences in data visualization type (See section 8.2.6).

With regards to the PA performance per participant, there was an increase of 1,598 steps; 0.529 miles; 0.249 miles/hour; 45.5 Kcal but a decrease in time spent on PA for 18 minutes per day, per participant. This decrease in duration of PA but increase in number of steps shows that the participants did more intense PA starting in the second week when social interaction was introduced. Nevertheless, based on the comments on Social Interaction (See section 8.2.7), it seems that the interaction offered by SocioPedometer had a wide spectrum of effects on participants, ranging from causing feelings of stress and pressure about personal PA levels, to neutral feelings, to encouraging participants to do more PA. A possible explanation for this spectrum is that the effect of social interaction in PA performance is affected by the individuals' personality type. Such association between the effect of persuasive technology, like SocioPedometer, and personality type has been recognized in a study by Halko & Kientz (2010). To fully elucidate the potential benefit of SocioPedometer in increasing PA levels, long-term and large sample size randomized control trials in an outpatient setting is required. Such trials should include heterogeneous participants in terms of age, gender, socioeconomic status, personality type, and experience with online SNS and smartphones. A similar trial with a randomized control trials (RCTs) study design should also be conducted to explore the association between online social interaction and PA performance. This type of trial could lead to the development of more effective social interaction techniques and allow exploration of effective methods of ecological momentary intervention (EMI) using social network system. Lastly, the online social interactions in this SocioPedometer study included two or more types of social interactions (viewing others' data, comparing data, sending message, receiving message, etc.) so that the independent contribution of any one of these components is difficult to establish. Hence, a more detailed and structured study to examine each type of social interaction's effects on PA performance is also warranted.

In conclusion, the results from the quantitative and qualitative analyses demonstrate that deploying SocioPedometer with self-management and social network features in daily life PA promotion is feasible. In addition, with respect to the persuasiveness of SocioPedometer, the results suggest that SocioPedometer influenced participants to change behavior levels with regards to PA, at least during the duration of study. The results varied for each participant, but most showed improved levels or maintenance of good levels of PA and increasing intensity of PA (See Table 8-8). Nonetheless, these results should be interpreted with caution because of the study limitations: small size and homogeneous characteristics of the sample, no other apps as a comparison, and not-standardized and not-validated outcome measures. To examine the usability, the sample size appears appropriate according to the Problem Discovery Rate Model which is widely used to serve in formative evaluation, like in this study (J. R. Lewis, 1993b; Nielsen & Landauer, 1993; Virzi, 1992). The model gives fairly good estimation that of 85% of usability problems will be revealed using five participants and almost 100% of problems using 14 participants (J. R. Lewis, 2006; Nielsen, 2000; Turner, et al., 2006). Nonetheless, the number of participants seems to be a bit low when the fact that it was a homogeneous sample population is taken into consideration. Our participants tended to be adult, female, college-educated, and already experienced with the technologies used in SocioPedometer (smartphones and online social interaction). Additional research would be needed to determine whether findings extend to a demographically more heterogeneous sample and to those who have no prior experience with smartphones and social interaction technologies. A similar issue arises when evaluating the feasibility of using SocioPedometer in PA promotion. Given the small sample and the relatively similar and high socioeconomic status of participants, findings may not generalize to the general and sedentary population. Thus, the findings are not conclusive, and will require validation from a larger trial study with a more representative population. In addition, while a change in the amount of PA performance per day during the month-long feasibility study was recorded (See Figure 8-2), caution should also be used when trying to interpret a connection between online social interaction and the PA data (See Figure 8-4) because of this study's limitations, especially its short duration of study and small sample size.

With regards to the validity of the PA data gathered, SocioPedometer was tested in controlled conditions —such as done in previous two studies (Boyce, Padmasekara, & Blum, 2012; Le Masurier & Tudor-Locke, 2003)— and shown to work fairly well. Also, participants of this study gave positive comments about its accuracy, especially since the number of steps it reported can be used as relative number to compare to previous numbers and see improvement? (See comments on section 8.2.2). Nevertheless, regardless of the participants' comments, a validity evaluation should still be conducted in the future. Such evaluation will give a greater credibility to the system, which will yield a more persuasive effect (Harri Oinas-Kukkonen & Harjumaa, 2008). A potential method to conduct a validity evaluation would be a comparison against other step monitoring devices, especially the widely known most accurate pedometer. As two previous studies show that this is the most feasible method to validate a steps counter over a long duration in free-living conditions (Schneider, Crouter, & Bassett, 2004; Tudor-Locke, Ainsworth, Thompson, & Matthews, 2002). These studies used different methods and different characteristics of the participants, but they both have agree that the magnitude of the error of step monitoring devices in counting steps number is not likely an important threat to the assessment of a free-living ambulatory population —such as the SocioPedometer subjects in this study— but may be a problem for a few populations such as older adults, people with chronic disease, or individuals with disability. Indeed, this threat to validity is also problematic when using the pedometer to assess PA in sedentary individuals who travel extensively by motor vehicle.

9.0 REVISITING THE MODEL, FRAMEWORK, AND PLATFORM IN LIGHT OF EVALUATION RESULTS

As mentioned earlier, PersonA systems – SocioPedometer and the PAMS Sharing Unit – were designed, implemented, and evaluated based on the model, framework, and platform of the Health Persuasive Social Network. Previously, the results from usability evaluation were discussed in terms of the users' perceptions of learnability, efficiency, memorability, error recovery, ease of use, and usefulness (Chapter 7 for the PAMS Sharing Unit and Chapter 8 for SocioPedometer). The observed physical activity behaviors of participants as well as their reactions to and experiences with the specific components of the systems —especially SocioPedometer— were discussed in Chapter 8. In this chapter, the results from the aforementioned evaluations are used to revisit the model, framework, and platform and further to support or refine them. This chapter presents a mix of the results that have not yet been presented along with insights from the results that have been presented in the previous chapters. It begins with a discussion of users' preferences to the fundamental characteristics of health persuasive social network in the model (Section 9.1); followed by the users' perception of the systems features proposed in the framework (Section 9.2) and the platform (Section 9.3). It concludes with a discussion of implications of these findings in the design of the Health Persuasive Social Network systems.

9.1 REVISITING THE MODEL OF THE HEALTH PERSUASIVE SOCIAL NETWORK

A formative evaluation of the characteristics of the model of the Health Persuasive Social Network was conducted using SocioPedometer with the aim of supporting useful characteristics and refining those that were shown not be useful. The evaluation was conducted mainly to get users' preferences of the characteristics proposed in the model. The model and its evaluation is a complement to a few prior studies including Rabin & Brock (2011), and Kailas, Chia-Chin, & Watanabe (2010). Unlike the work of Rabin & Brock that focuses on the mobile application's features or functions, the HPSN model focuses on fundamental characteristics which are usually used by application developers to select which technologies support the application. After selecting the technologies, the characteristics and the technologies are combined with the detailed user requirements that have been gathered, and together are used as a foundation to design application features. Thus, this HPSN model can be used as a blue print and simple guideline by developers to build mobile apps for PA promotion that consider health behavioral change strategies. Moreover, even though Rabin & Brock indicated that 3 of 15 features (target goal setting, problem solving, and behavioral enforcement) of three mobile apps that she evaluated are each consistent with a principle in SCT, they did not explain its association with the fundamental theories in more detail, including which principles or theoretical constructs of SCT that they referred.

On the other hand, the characteristic model of HPSN provides a detailed explanation of the relationship between each proposed characteristic and the widely applied health behavior theories. In addition, because the features that Rabin & Brock evaluated are mainly from the three mobile apps that they used (iTreadmill 3.1.0, iFitness Hero 1.0, and Exercise Tracker 1.12), the evaluation that they proposed is limited to those apps' features. For example, those three apps did not have social support features, therefore this study doesn't investigate social support even though implementation of social support in PA promotion has shown positive results (Klasnja, et al., 2009; Leahey, et al., 2010; K. Smith & Nicholas, 2008; B. Uchino, 2006). Finally, Rabin & Brock did not evaluate the persuasiveness of the apps whereas an implementation of persuasive strategies to a system increases the likelihood of an adoption of the system (Albaina, et al., 2009; BJ Fogg, 2007; Medynskiy & Mynatt, 2010; Toscos, et al., 2008). In contrast, the HPSN model uses SocioPedometer, which by design has social support functions and is designed using persuasive principles. This HPSN model is also an accompaniment to the Kailas, Chia-Chin, & Watanabe work which focuses on the important technical and nontechnical issues facing the commercialization of a wellness handset. They analyzed the wellness handset mostly from literature research market scan analysis. Unfortunately, the report did not explain the relationship of the technical and non-technical issues with existing behavior change theories. They mainly focus on whether or not the apps will be commercially successful.

To evaluate the proposed seven characteristics in the HPSN model, fourteen potential users were recruited through online advertisement. The participants in the model evaluation are the same as that of the SocioPedometer study (Refers to 7.1.1 and 8.1.3). To accommodate the HPSN model evaluation, at the end of the SocioPedometer interview, the participants were asked to rate the importance of the proposed seven fundamental mobile application's characteristics. The rate options given to them were as follows: 5=extremely important, 4=very important, 3=moderately important, 2=slightly important, 1=not important. Then descriptive analyses were performed on the characteristics ratings. The quantitative result of fundamental and desired characteristics of mobile apps for PA is summarized in Table 9-1. It seems that most of the characteristics were extremely important for them, with an average of 4.27, except the social characteristic, which alone rated lower with 3.62 (very important).

Table 9-1. Quantitative Results of User Preference for PersonA Characteristics

Characteristics	Mean	Standard Deviation
Personal	4.46	0.67
Sensible	4.46	0.67
Real Time	4.69	0.48
Secure	4.08	1.04
Mobile	4.54	0.52
Social	3.62	1.26
Persuasive	4.08	1.16

The SocioPedometer participants placed premium importance on the ‘Personal’ characteristic. A major benefit of implementing personal characteristics is the ability to tailor care to the individual person, for example by allowing users to choose how they would like to receive their information or even alerts. This is consistent with prior research indicating that providing personalized and tailored intervention materials will increase the likelihood of an intervention to succeed (Kirwan, et al., 2012; Lau, et al., 2011; Shuger, et al., 2011).

They also placed premium importance on ‘Sensible’. This is consistent with prior research indicating that automatic data collection not only can provide accurate and detailed estimates of PA information (in some circumstances and with additional input parameters) but also can reduce burdens on users or physical educators/researchers/physician when compared to direct or manual observation (Jonathan, et al., 2006; Raustorp, et al., 2011; Shuger, et al., 2011; Westerterp, 2009). The importance of the sensible characteristic is also supported by a statement indicating that health self-management regimes have to take into account the accuracy of the monitoring devices, the run in period required to ensure patients are safe and effective at self-measuring, the quality assurance of the monitoring device, and the frequency with which patients are required to self-measure (Ward, et al., 2010). A technology with sensible characteristics can potentially support the patients to self-measure the required data in long duration and in high frequency.

They also placed premium importance on 'Real Time'. This is consistent with prior research indicating that real-time feedback can be particularly important and useful to enhance and then maintain lifestyle changes of PA (Bickmore, et al., 2008; Hurling, et al., 2007; Lau, et al., 2011; Shuger, et al., 2011).

They placed premium importance on 'Secure'. This is consistent with prior research indicating that security and confidentiality play an important role for acceptance and usage of systems from users (patients) and clinicians (Terry & Francis, 2007; Wilkowska & Ziefle, 2011). The increasing demands to protect confidentiality and privacy in a healthcare system, and the potential liability issues, drive the need for the 'Secure' characteristic. The security characteristic has an important role in building the trust that physical activity and health (general) data will be stored securely. Employing proper security measures, such as utilizing a role-based access system, is an example of creating a secure, trusted, and confidential environment.

They placed premium importance on 'Mobile'. This is consistent with prior research indicating that mobile technologies that individuals routinely carry, such as mobile phones, can be a particularly effective platform for delivering PA encouragement or intervention as they are likely to be with the individual when he/she most needs the support (BJ Fogg, 2007; Revere & Dunbar, 2001; Tufano & Karras, 2005). This characteristic becomes more important when applied to outpatient interventions, since patients can carry them easily.

They placed importance on ‘Social’. This is consistent with prior research indicating that system facilitating social support can effectively motivate people for behavior change and effectively provide support when and where people make decisions affecting their health status (Klasnja, et al., 2009; Leahey, et al., 2010; K. Smith & Nicholas, 2008; B. Uchino, 2006).

They placed premium importance on ‘Persuasive’. This is consistent with prior research indicating that the persuasive factor in a system can indeed be effective to form initial excitement, to increase awareness of, and to provide motivation to increase physical activity levels in a fun and engaging way (Albaina, et al., 2009; BJ Fogg, 2007; Medynskiy & Mynatt, 2010; Toscos, et al., 2008).

Since all the characteristics have been implemented successfully in prior PA interventions and shown positive impact, and the characteristics have also been evaluated and given high scores in this research, grounding these characteristics in an application for PA promotion thus may increase its appeal and efficacy.

To fully align with the existing model of health behavior change, specifically the Transtheoritical Model, the PersonA systems should be deployed in the proper stages of behavior change. PersonA systems may be best suited when the users are in the *preparation*, *action*, and *maintenance* stages of the Transtheoritical Model (TTM). Locke and Lathman (2002) seem to agree when they suggest that the target audience of health behavior change should be individuals who have determined that the behavior change is important to them (*contemplation* or *preparation* stages of TTM). To whom that are in the *pre-contemplation* or *contemplation* stages, an educational program can be potentially deployed to make them ready in using the PersonA system (See Figure 9-1).

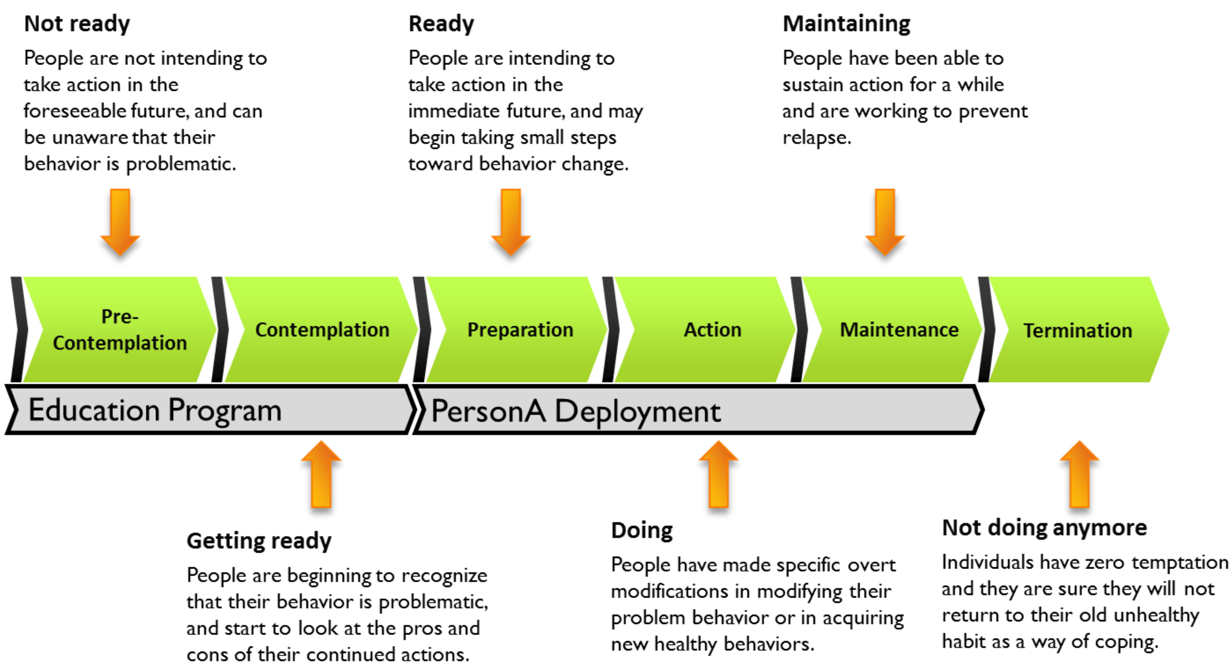

Figure 9-1. PersonA Intervention in the Transtheoritical Model

9.2 REVISITING THE FRAMEWORK OF THE HEALTH PERSUASIVE SOCIAL NETWORK

Using SocioPedometer, a formative evaluation of the PersonA framework was conducted with the aims of refining or supporting the framework. In this study, the evaluation was conducted mainly to get users' preferences with respect to the system features proposed in the framework. To evaluate the proposed system features in the framework, fourteen potential users were recruited through online advertisement. The participants, study design, and procedure for this evaluation are the same as that of the SocioPedometer study (Refers to 7.1.1 and 8.1.3). For SocioPedometer, one section of the usability questionnaire was designed to rate the importance of the proposed system features. The rate options given to the participants are as follows: 5=extremely important, 4=very important, 3=moderately important, 2=slightly important, 1=not important. Then, descriptive analyses were performed on the characteristics ratings. The quantitative results are summarized in Table 9-2. It seems that most of the system features are very important for participants, with an average of 4.09 (very important),; only peer and social features rated lower with an average of 3.58 (moderately important).

The fact that the self-management features (self-measurement, goal setting, self-monitoring, and self-comparison) are regarded as important is consistent with a few prior studies and literatures (Albaina, et al., 2009; Bodenheimer, et al., 2002; Consolvo, et al., 2006; Locke & Latham, 2002; Lorig et al., 1999; McManus, et al., 2010; Medynskiy & Mynatt, 2010; Rao, et al., 2010; Samoocha, Bruinvels, Elbers, Anema, & van der Beek, 2010; Toscos, et al., 2008). For example, in the case of using self-management features to monitor and to encourage PA, Locke and Lathman's (2002) findings suggest that the target audience should be individuals who have determined that the behavior change is important to them. They determine that one significant sign of this condition is when individuals already have a goal/target in doing PA and suggest that the goal should be set by the individual, or participatively with the help of an expert, such as a personal trainer. They also point out that what the individual has to do to meet her goal should not be ambiguous; for example, the program could follow the common format of PA guidelines set by government agencies. The goal should be a priority in her life, and it must be challenging, yet something that she believes she can realistically achieve. Moreover, they stress that the individual should receive incentives as she makes noticeable progress toward her goal, in addition to when she achieves the goal. One technology that may be most fit to deploy in this situation is persuasive technology. The technology is designed to provide feedback on how far over the goal the individuals have gone, or to provide an accomplishment when the individuals exceed the goal.

A similar theme arose for the social support features, although with considerably lower scores. The evaluation results are consistent with a few prior studies (Consolvo, et al., 2006; BJ Fogg, 2007; Harri Oinas-Kukkonen & Harjumaa, 2008; Khaled, et al., 2006; J. J. Lin, et al., 2006; Maitland, et al., 2006; Toscos, et al., 2008; Wiafe, et al., 2011). For example, Toscos, et al. (2008) reveal that sharing group step counts —similar to the peer and social comparison features in the framework of the HPSN —which was done as an effort to promote modeling of healthy behavior has been shown to have a positive relationship with activity levels in adolescent girls. In their study, the average step count for nearly all of the participants increased in the second and third weeks after the mobile phone application with social support features was introduced. Each of the three groups involved in the study were comprised of girls who were already “best friends” *yet* such technology provided increased effect of social support, especially in playing a part to reduce the barriers to physical activity experienced by adolescent girls. The barriers reduced through the social support include perceived barriers such as ‘lack of energy’ and ‘lack of time’; these were reduced through the power of a friend’s suggestion.

Table 9-2. Quantitative Result of User Preference of Self-Management System Features in PersonA Framework

Strategies	Functional Requirement	System Feature	User Preference Score	
			Average	Standard Deviation
Self-management	Self-measurement	A feature to record physical activity data easily	4.52	1.08
	Goal setting	A feature to set a target that a user want to accomplish	4.04	1.07
	Self-comparison	A feature to track current activity level against a predefined goal	4.39	1.03
	Self-monitoring	A feature to view historical (over time) data including target versus actual accomplishment and trend of a user's physical activity	4.57	0.79
Social Support	Peer and social comparison	A feature to access aggregate and other's data	4.22	0.85
		A feature to compare a user's data with that of others	4.26	0.81
	Peer and social support	A feature to receive encouraging comments	4.17	1.19
		A feature to post a status to wall (telling everybody about physical activity level that a user has been achieved and want to achieve)	3.48	1.27
		A feature to post a status to a user friend's wall (telling a close friend about physical activity that the user has been achieved and want to achieve)	3.74	1.25
		A feature to post a status to a user's group members (telling people who have similar or same experience/agenda about what physical activity a user has done and want she wants to achieve)	3.52	1.12

9.3 REVISITING THE PLATFORM OF THE HEALTH PERSUASIVE SOCIAL NETWORK

The platform of the Health Persuasive Social Network has been successfully and easily leveraged into two systems: PAMS Sharing Unit and SocioPedometer. This was possible because the design of the platform follows Object Oriented Design (OOD) principles. OOD is a designing process for a system with the main purpose of making a system modular with reusable components. The modularity and reusability are enabled by defining system components as objects that independently contain data and procedures that are then grouped together to represent an object or entity. The 'object interface', how the object can be interacted with, is also defined independently. The design is then implemented using Object-oriented programming (OOP). The techniques that may be used in this programming include *data abstraction*, *encapsulation*, *messaging*, *modularity*, *polymorphism*, and *inheritance*. Each object is capable of receiving messages, processing data, and sending messages to other objects. Each object can be viewed as an independent 'machine' with a distinct role or responsibility. The actions (or 'methods') of these objects are closely associated with the object. Following object oriented design and programming, the PersonA system is divided into three big groups of computer code: System-User Interaction, Data Management and Logical Functions, and a Social Network System. (See more detailed explanation in 6.1.1.2). This design and programing approach allows the computer code to be independent and easily used multiple times and even in multiple applications.

To promote PA, a definition of what data/information is needed by individuals to quantify PA performance in practicing behavior change is crucial. Thus, an analysis to define PA data items was conducted in this study. The analysis reveals that the four most important data items needed in the promotion are energy expenditure (or calories burned), duration of physical activity, distance travelled, and average velocity. The duration and average velocity (closely related to ‘PA intensity’) are clearly mentioned as PA data items in the suggestion by the Centers for Disease Control and Prevention (CDC) to quantify the amount of physical activity required for health benefits. ‘Calories burned’ was proposed because it’s usually the most interesting information needed by persons trying to balance calorie intake and outtake as a target in their diet and PA program. ’Distance’ was proposed because it is the most widely used and easily measured as a measurement in PA promotion for the general population. Additional data items may be required in the health intervention context. For example, number of steps is considerably important for measuring PA in the general population. It is important because it is inspired by the public acceptance of ’10,000 steps/day’ as the benchmark of an active life style. Influenced by the analysis, the PAMS Sharing Unit implements the four data items while SocioPedometer implement ‘number of steps’ in addition to the other four data items.

Another advantage of using the HPSN platform as the basis in a system development is the capability of the platform to integrate several systems. An example of the integration happens in the PAMS system where the Monitoring Unit works as an independent yet integrated to the Sharing Unit. To maintain the independency and the integration, a database sharing approach is best chosen. In Android operating system (OS), database sharing is implemented through a *content provider* object. *Content Providers* are a generic interface mechanism that lets system developers share data between applications. Content Providers feature full permission control over the database and are accessed using a simple URI model. In Android, a uniform resource identifier (URI) is a string of characters used to identify a name or a resource. Shared content can be queried for results in addition to supporting write access. As a result, any application with the appropriate permissions can add, remove, and update data from any other applications —including some native Android databases (Meier, 2009). By implementing this database sharing, the development of two or more systems —the PAMS Sharing Unit and the Monitoring Unit— can be completely independent *yet* still integrated. The one requirement is just an agreement about the database and data item definitions.

10.0 SUMMARY, CONTRIBUTIONS, AND OPPORTUNITIES FOR FUTURE WORK

10.1 SUMMARY

This dissertation has made a variety of contributions to and suggested opportunities for future work for the fields of Human-Computer Interaction (HCI), Ubiquitous Computing (UbiComp), Persuasive Technology, Software Engineering, Biomedical Health Informatics (BHI), Rehabilitation, and Public Health. It began in Chapter 1 by motivating the problem space of using two strategies of health behavior change, which is supported by persuasive technologies, to support and encourage regular and varied physical activity. The physical activity was a particularly timely type of lifestyle behavior change suggested to reduce the effect of some other worldwide health problems such as obesity, high blood pressure, and osteoporosis.

In Chapter 2, overviews of the theories and models referred to in this dissertation were provided. These theories and models helped drive the design of the model, framework, platform, and systems of the Health Persuasive Social Network. As an implementation and tools to evaluate the Health Persuasive Social Network, a persuasive technology called PersonA was introduced. PersonA followed the tradition of other behavior modification interventions and drew design inspiration from the theories in behavior psychology, health behavior and technology, and technological development. The theories in behavior change include The Health Belief Model (HBM), Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) by Fishbein & Ajzen (1975, 1980), The Elaboration Likelihood Model (ELM) by Petty & Cacciopo (1980s), Social Cognitive Theory (SCT) by Bandura (1977-2001), and Uchino's Social Support and Physical Health Link (2006). To design the model, the theories in the health behavior change area and at the intersection of health behavior change and technology development are referred to. The include Use and Gratification Theory (UGT), Common Bond and Common Identity Theory, the Technology Acceptance Model (TAM) by Davis and Bagozzi (1989, 1992), The Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003), and the Fogg Behavioral Model (FBM) (2009). Finally, to design and evaluate the Health Persuasive Social Network framework and platform, the following theories and models in technology development were referred to: the Fogg Functional Triad and Design Principle by Fogg (2003), the Fogg Eight-Step Design Process by Fogg (2009), Persuasion System Design (PSD) by Oinas-Okkunen and Harjumaa (2009), and System Development Life-cycle (SDLC) with the Waterfall Model and its dependence originally proposed by Royce (1970).

In Chapter 3, health intervention strategies —self-management and social support— and a few studies implementing the strategies as well as an analysis of advances in technologies that are potentially relevant to the design of the Health Persuasive Social Network were discussed. The discussion of self-management started with the fundamental concept of self-management and its required masteries, followed by discussion of a few studies that have implemented the strategy and have shown positive results. The section then examines the fundamentals of another strategy — social support— that is also informed by a few studies that have implemented the strategy and shown positive results. This chapter elucidates the design decisions of the Health Persuasive Social Network platform and systems as well as the method used to evaluate the platform and systems. Another concept that is also overviewed in this chapter is the concept of persuasive technology and its implementations in recent health intervention studies. This chapter ends with an analysis of three advanced technologies (sensing technology, smartphone, and social network system) that have the potential to be combined as a persuasive technology to promote more active PA.

As was apparent from Chapter 2 and 3, designing technology to help individuals get from the behavior or lifestyle they *currently have* to the lifestyle they *want* is complex. The driving goal of lifestyle behavior change technologies is to persuade individuals to change their behavior, and then get them to sustain the changed behavior so that it becomes a regular part of everyday life. To that end, Chapter 4, proposed a set of models to inform and simplify the understanding and the design of technologies to support lifestyle behavior change. The first one is a model describing the fundamental and preferred characteristics of the Health Persuasive Social Network. The second one is a model depicting the position of the Health Persuasive Social Network in a health intervention context and shows advances in the current persuasive technology context. These models incorporate the theories and related work described in Chapter 2 and 3.

After that, the position of the Health Persuasive Social Network in health intervention and technology contexts and its characteristics were discussed in Chapter 4. A detailed explanation of *what*, *why,* and *how conceptually* the suggested health behavior change strategies and design principles —which are summarized in the Health Persuasive Social Network models— should be transformed into system requirements and further be implemented as system features in Health Persuasive Social Network is then presented in Chapter 5. Five practical guidelines to developing and evaluating the technology were proposed. The guidelines include incorporation of a self-management strategy and a social support strategy, automatic data collection and real time feedback, persuasive strategies, and the security and confidentiality of PersonA.

In Chapter 6, a detailed explanation of *how technically* the Health Persuasive Social Network framework, which incorporates the suggested health behavior change strategies and design principles, should be transformed into system requirements and further be implemented as system features is presented. The explanation provides a detailed design for hardware and conceptual architecture and a detailed explanation of PersonA's system features. Discussion of two cases implementing the Health Persuasive Social Network —wheelchair user case (PAMS Sharing Unit) and general population case (SocioPedometer)— with their characteristics and technical considerations follow. PAMS was designed especially to capture physical activities that are part of the lifestyle of manual wheelchair users and to motivate them to be physically active via web-based or mobile social networking applications, while SocioPedometer was leveraged to attract the general population to have more physical activity in terms of number of steps that they take every day.

In Chapter 7, a study to evaluate the usability aspect of the PAMS Sharing Unit was described. The evaluation was conducted mainly to get users' perceptions about learnability, efficiency, memorability, error recovery, ease of use, and usefulness of the system. It was conducted in the development and evaluation phases, where a group of potential users and clinicians evaluated the PAMS Sharing Unit to ensure that the requirements and features meet with their needs. The study's purposes included determining which features are most useful; which features are most suitable in web apps, mobile apps, or both; what the pros and cons of the features are and how to mitigate the cons, and what kind of interface is most effective/preferable, etc. The results of this evaluation were used to refine the system and also to evaluate the model, framework, and platforms of the Health Persuasive Social Network (described more detail in Chapter 9).

Chapter 8 reports the results from a usability and feasibility evaluation of SocioPedometer. The evaluation serves several purposes, mainly technological: to find out whether SocioPedometer is usable, reliable, accepted by users, and persuasive; to find out how comprehensively data can be collected using SocioPedometer; to evaluate whether all research protocols and tools are comprehensive and appropriate; to determine acceptability of the intervention; and to reveal other technology deployment issues to prepare for larger and clinical trials. The results of this evaluation were also used to refine the system and to evaluate the model, framework, and platforms of the Health Persuasive Social Network (described more detail in Chapter 9).

In Chapter 9, the results from the aforementioned evaluations (Chapter 7 and 8) were used to revisit the model, framework, and platform and to further support or refine them. This chapter presents a mix of results that had not yet been presented in the paper as well as insights from results presented in previous chapters. It begins with a discussion of users' preferences with regards to fundamental characteristics; it is then followed by the users' perception of the system features proposed in the framework and platform. It concludes with a discussion of the implications of these findings in the design of a health persuasive social network.

This dissertation makes several contributions, which are described in the next section. Opportunities for future work then follow.

10.2 CONTRIBUTIONS

Researchers from around the world have been trying to find the best method to overcome or to manage chronic diseases or disabilities because the number of people with these conditions has significantly increased, especially in the developed countries. For example, in the US, 50% of Americans have chronic disease and 50% of those have more than one chronic disease; also, seven of every 10 Americans who die each year die of a chronic disease (US Centers for Disease

Control and Prevention (CDC), 2008). Unfortunately, the current number for chronic disease is projected to continuously climb unless all sectors of society engage in creative solutions to reducing the number and expands disease prevention. One impending demographic shift is the aging of the baby boomers. In 2011, the baby boomer generation began turning 65; by 2030, approximately 20 percent of the U.S. population will be over age 65, a dramatic increase from the current level of 13 percent (US Census Bureau, 2004). The current statistics related to chronic disease has led the US government to direct much effort and funding toward treatment for and research of chronic diseases, with a total of 75%-83% of the $2 trillion national medical-care costs currently being spent (US Centers for Disease Control and Prevention (CDC), 2008). This spending will be much bigger in the future with the increasing prevalence of chronic disease. According to one study, Medicare spending is predicted to increase from 3 percent of U.S. gross domestic product in 2006 to 8.8 percent by 2030 (Thorpe & Howard, 2006).

Similarly, with respect to disability, it is estimated that 15% of US adults have disability, with a much bigger percentage for the elderly (approximately 54.2 percent of adults aged 65 or older). Three hundred ninety seven billion dollars in health care costs (26.7% of all US adults health care costs) was spent on this population in 2006 (US Centers for Disease Control and Prevention (CDC), 2008). Persons with chronic disease(s) and disabilities have higher care costs because of poorer health status, which leads to more healthcare services being required; they experience more chronic conditions and more access barriers, and so may have more frequent emergent care episodes. In addition, the technologies or tools that can help and persuade the persons to perform self-management and social support as part of health behavior change are not widely available at a relatively cheap cost. Therefore, research studies to explore any potential solution to decrease the number of people with chronic disease or disability, to decrease the health care costs or to increase the intervention needed to prevent/delay chronic disease or disability is strongly warranted. Those research studies that include the development of health related applications might be deployed to motivate people towards healthy behavior, and thereby possibly delay or even prevent medical problems as well as improve quality of life.

As such, this dissertation has made several contributions both in theoretical and practical knowledge to the fields of HCI, UbiComp, Persuasive Technology, Software Engineering, Rehabilitation, BHI, and Public Health. These contributions, which predominantly come out of the results discussed in Chapters 3 through 9, include:

a) A complete guideline to develop health persuasive social network

The HPSN model informs the correlation among health behavioral change, psychology, persuasion, and a social network. The model may be useful in the areas of behavioral change interventions and persuasive technology development, especially to help understand the fundamental and preferred characteristics of technology needed to support individuals in performing health behavior change practices. The models also inform the position of each characteristic in health behavior change strategies and currently available technologies. This can be used as a blue print or a guideline for system developers to translate the strategies into ready to implement system features. Even though the model was purposefully designed for health behavior change for PA, it is also expected to be applicable in other behavioral interventions. The model also made it possible to identify various strategies, methods, and technologies of health behavior change which are a novel contribution to the health intervention theory. Although the PSD Framework proposed by Oinas-Kukkonen (2008) is currently regarded as the most complete guideline for development and evaluation of persuasive systems, it is designed for a general context, not for a health behavior change context. There is currently no framework for the development and evaluation of persuasive systems in a health behavior change context. The Framework of the Health Persuasive Social Network offers fundamental, complete, and practical guidelines for developing and evaluating a persuasive system specially designed for health behavior intervention.

b) An innovative and integrated communication platform

The HPSN Communication Platform integrates sensible technologies (accelerometer and physical activity sensors) as data entry points, a smart phone as personal gateway/hub, a health portal, and a social network system (Facebook). Using this platform, it is expected that health related data could be transmitted dynamically, effectively, and efficiently among those technologies without much human effort. This platform allows automatic data collection and immediate feedback. The importance of immediate feedback has been recognized in a few studies as another important characteristic of supporting systems for health intervention (Bickmore, et al., 2008; Hurling, et al., 2007; Lau, et al., 2011; Shuger, et al., 2011). Automatic data collection minimizes errors in data entry caused by human limitations and makes users feel more comfortable. The importance of 'sensible' has been recognized in a few studies as one of the most important characteristics of supporting systems in health intervention (Jonathan, et al., 2006; Raustorp, et al., 2011; Shuger, et al., 2011; Ward, et al., 2010; Westerterp, 2009). Both data collection and immediate feedback are expected to lead to better adherence to health programs.

c) An innovative platform of health persuasive social network system

The HPSN System helps users to engage in self-management and social support practices to persuade individuals to perform more intense physical activity. Self-management is technically implemented using the function of self-measurement, goal setting, and self-monitoring while social support is technically accommodated through social comparison and social interaction functions implemented using the Facebook framework. All of these functionalities are implemented in the smartphone platform with the main purpose of providing real-time feedback and interaction wherever and whenever users want. This 'wherever and whenever' availability can be provided because of the intrinsic nature of the smartphone: always on, always carried on the person, and always connected.

d) Innovative implementation of the Self-management, Social Support, and Persuasiveness concepts using current technologies

The implementation of the self-management concept, social support concept, and persuasive strategy altogether using currently available advanced-technologies in health intervention and rehabilitation is novel. Researchers have been trying to implement these three concepts solely but not altogether (Agarwal & Lau, 2010; Albaina, et al., 2009; Bodenheimer, et al., 2002; Campbell, et al., 2004; Ciemins & Sorli, 2010; Leahey, et al., 2010; J. J. Lin, et al., 2006; Macvean, et al., 2008; McManus, et al., 2010; Medynskiy & Mynatt, 2010; Postma, et al., 2009; Robinson, et al., 2010; Ryan & Sawin, 2009). Even though most studies have reported improved health outcomes after the implementation of each concept (Self-management, Social Support, and Persuasive Technology), there is still questions with respect to how to accommodate these three concepts altogether in one health intervention and rehabilitation program, what kind of technology can support or accommodate those three, and whether all three together can have a stronger impact. This dissertation may partly answer the aforementioned questions.

e) *An innovative model of study to estimate online peers' effect on physical activity performance*

The effect of social networks on health behavior has been well-documented (Christakis & Fowler, 2007, 2008; Leahey, et al., 2010; Robinson, et al., 2010; Tilkeridis, et al., 2005; Voorhees, et al., 2005; Vu, et al., 2006). With the fact that 72% of US Internet users currently have a Facebook account (Facebook, 2012), the potential association between online social interactions and health outcomes cannot be overstated. Unfortunately, the model, framework, and tools to evaluate this potential association are not available. The Health Persuasive Social Network offers a promising solution in the area of PA promotion because it allows the recording of all online social interactions as well as physical activity so that researchers can estimate the association between the interactions and PA.

10.3 OPPORTUNITIES FOR FUTURE WORK

To fully elucidate the potential benefits of the Health Persuasive Social Network, more varied health intervention contexts, a larger amount of and a more heterogeneous population of participants, and more well structured studies in a daily life setting are required. First, testing these in a variety of contexts would be useful to examine the acceptance and generalizability of the model, framework, and platform. In addition to physical activity, health contexts where the Health Persuasive Social Network may be applied include blood pressure control (Brownstein, et al., 2007; Cappuccio, Kerry, Forbes, & Donald, 2004; Han, 2011; McManus, et al., 2010), diabates (Ciemins & Sorli, 2010; van Dam, et al., 2005), and weight control (Bonomi & Westerterp, 2012; Gourlan, Trouilloud, & Sarrazin, 2011; Rejeski et al., 2011; Shuger, et al., 2011). Next, having a larger amount of and a more heterogeneous population of participants will add psychological, social, and cultural considerations into the model and framework. These considerations have been recognized as important in building a system to promote health behavior change in a few prior studies (Consolvo, et al., 2006; BJ. Fogg, 2003; Harri Oinas-Kukkonen & Harjumaa, 2008; Khaled, et al., 2006; Maitland, et al., 2006) and need to be explored in more detail to refine or to support the model and framework. Since there are many potential factors involved in health behavior change such as personality, time of year, environment, work setting, education, age , gender, ability to perform PA related to physical disability, ability to perform PA related to physical chronic disease, familiarity with technology, more well designed and structured studies in daily living are highly warranted. For example, a preliminary study to analyze personality and social characteristics of participants should be done before delivering intervention using Health Persuasive Social Network because the response and effect of social interaction for each participant may be different depending on their personality. An exploratory study indicates that there is some promise to using personality traits as a method for adapting persuasive strategies to better fit the needs of users of health-promoting mobile health applications (Halko & Kientz, 2010).

The initial usability study of the PersonA systems identified a number of additional features suggested by users and clinicians to technically improve the systems. Those features include live news feed showing current a ‘best performer’ in each and every category, for example: the highest energy expenditure of the week. This feature can then be combined with the ability of other users to give rewards or greetings. Another potential content for this live news feed is a list of users currently performing PA. One technical study that results imply should be conducted is an implementation of ‘performance based’ recommendations. That is, machine learning can be applied so that the machine will recognize the habits and performance of users then give a recommendation to the users or to the clinicians/trainer to further develop the intervention materials.

To increase the internal and external validity of the PersonA system—such as SocioPedometer— in supporting PA interventions, future studies should consider the following:

1. Including a bigger sample size and more heterogeneous participants in terms of age, gender, socioeconomic status, personality, and experience with online SNS and smartphone. For example, a younger population such as high school students will be the best target population for SocioPedometer for a number of reasons: a) compared to an older population such as university students, teenagers stereotype includes less educated in physical activity and doing less physical activity. If, as a result a study, the PersonA give positive effects to them, using The Transtheoritical Model, their behavior transition before joining the study and after joining the study will be significantly recognized and then be measured easier; b) Their seasonal factors –which could be confounding factors – such as activity factor during exam-week or travelling weeks in holiday weeks (such as fall break or Thanksgiving) will not be as significant as university students’; c) Teens usually are more narcissistic compared to older people. Thus, teens also love to be in an ‘elite group’ and share it with everybody. These would boost the social interactions that we expect to have in this experiment (Toscos, et al., 2008; Toscos, Faber, An, & Gandhi, 2006;

Voorhees, et al., 2005) d) Teens usually have more time to socialize or play; compared to those in college; and e) Teens usually work better with peers compared to older people. One study found that social support from friends (peers) when compared with that from parents or siblings, had the strongest relationship with physical activity levels (Duncan, et al., 2005).

2. Deploying pre-screening of the participants in terms of their personality (tending to be personal or social) and expected levels of behavior change based on The Transtheoritical Model (See 2.1.4); the PersonA system should be most effective when users are in the *preparation*, *action*, and *maintenance* stages of the Transtheoritical Model. To prepare participants to be ready in performing self-management and social support practices using PersonA, an educational program would be needed when users are in the *pre-contemplation* or *contemplation* stages (See Figure 9-1).
3. Using SocioPedometer with and without online social interaction to examine the effect of online social interaction in PA performance.
4. Deploying SocioPedometer with social comparison and social support to examine the different effects of these types of social interaction on PA performance.

With regards to the validity of the PA data gathered, SocioPedometer has been tested in controlled conditions —such as done in two previous studies (Boyce, et al., 2012; Le Masurier & Tudor-Locke, 2003)— and shown to work fairly well. Also, participants gave positive comments about its accuracy (See comments on 8.2.2). Nevertheless, regardless of the participants' comments, a validity evaluation still should be conducted in the future. Such an evaluation can give the system greater credibility which will yield a more persuasive effect (Harri Oinas-Kukkonen & Harjumaa, 2008). For such an evaluation, a potential method that can be applied is a comparison against other step monitoring devices, especially the widely known most accurate pedometer. Until now, that's the most feasible method to validate a steps counter in a long duration of free-living conditions such as done by two studies (Schneider, et al., 2004; Tudor-Locke, et al., 2002). Thought the studies used different methods and participant had different characteristics, they both found that the magnitude of the error in counting steps is not likely an important threat to the assessment of a free-living ambulatory population —such as this SocioPedometer' participants— but may be a problem when monitoring special populations such as older adults, people with chronic disease, or individuals with disability. Indeed, this threat to validity is also problematic when using the pedometer to assess PA in sedentary individuals who travel extensively by motor vehicle.

APPENDIX A.

CONSENT FORM FOR PAMS USABILITY STUDY

[Please see the next page]

CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

TITLE: Development and Evaluation of Physical Activity Monitoring and Sharing (PAMS) Platform

PRINCIPAL INVESTIGATOR:
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SOURCE OF SUPPORT: Department of Defense (DoD)

Why is this research being done?

The purpose of this study is to develop and evaluate a physical activity monitoring and sharing system (PAMS) that allows wheelchair users with spinal cord injury (SCI) to monitor their own physical activity levels and share the information with others such as friends and family. You are being asked to help us to evaluate that sharing component of the system. The system can run on a smart phone or a computer. The smart phone version allows you to see a brief summary of your own physical activity and to compare your physical activity levels with the average of your group. The computer version is a website that allows you to track your own physical activity levels, share your physical activity levels with others, setup your goals, posting messages to encourage others, setting up and accepting physical activity challenges, and selecting options for reminders etc.

Who is being asked to take part in this research study?
You have been invited to participate in this research study because you are between 18-65 years of age, have a spinal cord injury, use a manual wheelchair for mobility, and have experience using a computer. Up to 20 subjects will be recruited to participate in this study.

What procedures will be performed for research purposes?
If you decide to take part in this research study, you will be asked to pay one visit to the HERL (Bakery Square Locations), Pittsburgh, PA. The visit will take no longer than 2.5 hours.

You will first complete two questionnaires on demographics and your experience with mobile phone and social networking sites, respectively. You will then be given an orientation and demonstration of the system both running on computer and smart phone. After the introduction, you will be asked to perform a number of tasks such as logging in/out, locating your physical activity information, locating physical activity information of others, setting up your physical activity goal etc. You will be asked to talk loud about your thoughts while performing these tasks. The evaluation process will be recorded on video which will be used as a reference for further system refinement and for data analysis. The recordings will be transcribed by study staff and stored without identifiers and will not be shared with investigators outside the research team. Then, you will be asked to complete a customized usability questionnaire to gather feedback on the overall usability of the system. At the end to this process, you will be asked to join an interview session where the investigators will ask for your suggestions on the system design and features beyond those have been implemented in the current system. The interview session will be audio-recorded.

What are the possible risks, side effects, and discomforts of this research study?
The risks involved in this study may include inconvenience of the length of time (i.e. 2.5 hours per visit) required to participate. You may experience fatigue due to the mental activities during the evaluation or completing the questionnaire. You will be given rest breaks as needed. As private information is collected about you as part of this study, there is a risk to your privacy and confidentiality. The research staff will take every precaution to protect your identity and the confidentiality of the information collected about you.

What are possible benefits from taking part in this study?
You will not directly benefit from participating in this study. The benefit to society in general is that this information will be useful in the development and evaluation of physical activity measurement system for manual wheelchair user population with spinal cord injury.

Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?
Neither you, nor your insurance provider will not be charged for any of the procedures performed for the purpose of this research study.

Will I be paid if I take part in this research study?
You will not incur any direct costs as a result of your involvement in this study. You will be compensated $50.00 for completing the study. If you do not complete the study, you will be compensated $25.00.

Who will know about my participation in this research study?

Any information about you obtained from this research will be kept as confidential (private) as possible. All records related to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. You will not be identified by name in any publication of the research results unless you sign a separate consent form giving your permission (release). We may share your data with other researchers outside of this research project who are also interested in studying activity monitors, but they will not receive any of your personal identifiers, including videos. The videotapes will not be de-identified for research purposes and confidentiality will be maintained to the best of our ability.

At the end of this study, any records that personally identify you will remain stored in locked files and will be kept for a minimum of seven years. In unusual cases, your research records may be released in response to an order from a court of law. It is also possible that clinical coordinators from the Human Engineering Research Laboratories, authorized representatives from the University of Pittsburgh Research Conduct and Compliance Office or the Department of Defense U.S. Army Medical Research and Material Command Human Research Protection Office may review your data for the purpose of monitoring the conduct of this study. Also, if the investigators learn that you or someone with whom you are involved is in serious danger or potential harm, they will need to inform the appropriate agencies, as required by Pennsylvania law.

Will this research study involve the use or disclosure of my identifiable medical information?

This research study will not involve the use or disclosure of your identifiable medical information. This study does not involve access to any of your clinical or medical records.

Is my participation in this research study voluntary?

Yes! Your participation in this study is completely voluntary. You may refuse to take part in it, or you may stop participating at any time, even after signing this form. Your decision will not affect your relationship with the University of Pittsburgh or the University of Pittsburgh Medical Center, nor will you lose any benefits that you might be eligible for because of what you decide. To formally withdraw your consent for participation in this research study you should provide a written and dated notice of this decision to the principal investigator of this research study at the address listed on the first page of this form.

May I withdraw, at a future date, my consent for participation in this research study?

You may withdraw, at any time, your consent for participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above. Any identifiable research information recorded for, or resulting from, your participation in this research study prior to the date that you formally withdrew your consent may continue to be used and disclosed by the investigators for the purposes described above.

If I agree to take part in this research study, can I be removed from the study without my consent?

The investigator(s) may stop your participation in this study without your consent for reasons such as: it will be in your best interest; you do not follow the study plan; or you are determined to be ineligible.

****

VOLUNTARY CONSENT

The above information has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that such future questions will be answered by a qualified individual or by the investigator(s) listed on the first page of this consent document at the telephone number(s) given. I understand that I may always request that my questions, concerns or complaints be addressed by a listed investigator.

I understand that I may contact the Human Subjects Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668) to discuss problems, concerns, and questions; obtain information; offer input; or discuss situations in the event that the research team is unavailable.

By signing this form, I agree to participate in this research study. A copy of this consent form will be given to me.

______________________________ ________________

Participant's Signature Date

CERTIFICATION of INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions as they arise. I further certify that no research component of this protocol was begun until after this consent form was signed.

_______________________________________ __________________________

Printed Name of Person Obtaining Consent Role in Research Study

_____________________________________ _____________

Signature of Person Obtaining Consent Date

APPENDIX B.

CONSENT FORM FOR USABILITY AND FEASIBILITY STUDY OF SOCIOPEDOMETER

[Please see the next page]

University of Pittsburgh

School of Health and Rehabilitation Sciences

Department of Health Information Management

CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

TITLE: Persuasive Social Network System for Physical Activity (PersonA) – Usability Study

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SOURCE OF SUPPORT: Department of Defense (DoD)

Why is this research being done?

As an introduction, the purpose of this study is to develop and evaluate persuasive social network for physical Activity (PersonA) that combines automatic input of physical activity data, smartphone, and social networking system (SNS). PersonA is designed to intelligently and automatically receive raw PA data from the sensors in the smartphone, calculate the data into meaningful PA information, store the information on a secure server, and show the information to the users as persuasive and real-time feedbacks or publish the information to the SNS to generate social support. You are being asked to help us to evaluate this system. The PersonA-Pedometer runs on a smart phone or a computer platform. The PersonA-Pedometer running on computer is a website that allows you to track your own PA levels, share your PA levels with others, setup your goals, posting messages to encourage others, setting up and accepting PA challenges, and selecting options for coaching reminders etc. The PersonA running on smartphone has similar functions with that of the computer version.

Who is being asked to take part in this research study?

You have been invited to participate in this research study because you are between 18-65 years of age, able to operate computer and smartphone, not having difficulty to walk or run, not having breathing problem or breathing related disease, and not having cardiovascular disease. Up to 7 subjects will be recruited to participate in this study.

What procedures will be performed for research purposes?

If you decide to take part in this research study, you will be asked to pay two visits to the Department of Health Information Management on the 6^{th} floor of Forbes Tower, Meyran Ave and Forbes Ave, Pittsburgh, PA 15260. Each visit should be completed within 2 hours. The research personals responsible for conducting this research are experts in health information management.

Before evaluation of our system start, the purpose and overall procedure of the study will be explained to you. First, you will be asked to complete a questionnaire regarding your demographic information and a questionnaire about your experiences with mobile phone, Internet, and social networking system. Researchers will then give a brief orientation and demonstration of the system both running on computer and smart phone. To get the real experience of using the system, you will be asked to use it for four weeks in your daily life. After four weeks, you will be asked to come back to HIM where you will be asked to perform a number of tasks; for example: task to locate your physical activity information. Once the evaluation process is complete, researchers will ask you some follow-up questions for clarification, if needed. The evaluation process will be recorded on video which will be used as a reference for further system refinement and will be transcribed for data analysis. The recordings will be transcribed by study staff and stored without identifiers and will not be shared with investigators outside the research team. Then, you will be asked to complete a customized usability questionnaire to gather feedback on the overall usefulness of the system. At the end to this process, you will be asked to join in-depth interview. In this interview, researcher will ask general and open question about the system. For example, the researcher will ask you about suggestions to improve the system.

What are the possible risks, side effects, and discomforts of this research study?

The risks involved in this study may include inconvenience of the length of time (i.e. 2 hours per visit) required to participate. You may experience fatigue due to the mental activities during the evaluation or completing the questionnaire. You may discontinue the study at any time.

Privacy and Confidentiality: Every effort will be made to make sure that the information about you obtained from this study will be kept strictly confidential. As private information is collected about you as part of this study, there is a risk to your privacy and confidentiality. The research staff will take every precaution to protect your identity and the confidentiality of the information collected about you. Any electronic or hard/paper copies of the information collected about you will be stored in a secured location. Any copies that contain information that could be used to identify you (such as your name, address, date of birth, etc., will be stored separately from any information that does not contain identifiers. Only those individuals who are authorized to review your information will have access to it.

Because there may be other risks associated with participating in multiple research studies, you must tell the research staff about any other studies you are currently participating in, both within and outside of the University of Pittsburgh.

What are possible benefits from taking part in this study?
The system may potential to promote your physical activity levels because you may be encouraged by using this system to perform more walking. The system will provide feedback and also capability to you to perform positive social support. The benefit to society in general is that this information will be useful in the development and evaluation of physical activity measurement and evaluation system for general population.

Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?
Neither you, nor your insurance provider will not be charged for any of the procedures performed for the purpose of this research study.

Will I be paid if I take part in this research study?
You will not incur any direct costs as a result of your involvement in this study. You will be compensated $50.00 for completing the study.

Who will pay if I am injured as a result of taking part in this study?
If you believe that the research procedures have resulted in an injury to you, immediately contact the Principal Investigator who is listed on the first page of this form. Emergency medical treatment for injuries solely and directly related to your participation in this research study will be provided to you by the hospitals of UPMC. Your insurance provider may be billed for the costs of this emergency treatment, but none of those costs will be charged directly to you. If your research-related injury requires medical care beyond this emergency treatment, you will be responsible for the costs of this follow-up care. At this time, there is no plan for any additional financial compensation.

Who will know about my participation in this research study?
Any information about you obtained from this research will be kept as confidential (private) as possible. All records related to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. You will not be identified by name in any publication of the research results unless you sign a separate consent form giving your permission (release). We may share your data with other researchers outside of this research project who are also interested in studying activity monitors, but they will not receive any of your personal identifiers. The videotapes will not be de-identified for research purposes and confidentiality will be maintained to the best of our ability.

At the end of this study, any records that personally identify you will remain stored in locked files and will be kept for a minimum of seven years. In unusual cases, your research records may be released in response to an order from a court of law. It is also possible that authorized representatives from the University of Pittsburgh Research Conduct and Compliance Office may review your data for the purpose of monitoring the conduct of this study. Also, if the investigators learn that you or someone with whom you are involved is in serious danger or potential harm, they will need to inform the appropriate agencies, as required by Pennsylvania law.

Will this research study involve the use or disclosure of my identifiable medical information?

This research study will not involve the use or disclosure of your identifiable medical information. This study does not involve access to any of your clinical or medical records.

Is my participation in this research study voluntary?
Yes! Your participation in this study is completely voluntary. You may refuse to take part in it, or you may stop participating at any time, even after signing this form. Your decision will not affect your relationship with the University of Pittsburgh or the University of Pittsburgh Medical Center, nor will you lose any benefits that you might be eligible for because of what you decide. To formally withdraw your consent for participation in this research study you should provide a written and dated notice of this decision to the principal investigator of this research study at the address listed on the first page of this form.

May I withdraw, at a future date, my consent for participation in this research study?
You may withdraw, at any time, your consent for participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above. (Note, however, that if you withdraw your consent for the use and disclosure of your identifiable information for the purposes described above, you will also be withdrawn, in general, from further participation in this research study.) Any identifiable research information recorded for, or resulting from, your participation in this research study prior to the date that you formally withdrew your consent may continue to be used and disclosed by the investigators for the purposes described above.

If I agree to take part in this research study, can I be removed from the study without my consent?
The investigator(s) may stop your participation in this study without your consent for reasons such as: it will be in your best interest; you do not follow the study plan; or you experience a study-related injury.

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VOLUNTARY CONSENT

The above information has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that such future questions will be answered by a qualified individual or by the investigator(s) listed on the first page of this consent document at the telephone number(s) given. I understand that I may always request that my questions, concerns or complaints be addressed by a listed investigator.

I understand that I may contact the Human Subjects Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668) to discuss problems, concerns, and questions; obtain information; offer input; or discuss situations in the event that the research team is unavailable.

By signing this form, I agree to participate in this research study. A copy of this consent form will be given to me.

____________________________ ________________
Participant's Signature Date

CERTIFICATION of INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions as they arise. I further certify that no research component of this protocol was begun until after this consent form was signed.

______________________________ ____________________

Printed Name of Person Obtaining Consent | Role in Research Study

______________________________ __________

Signature of Person Obtaining Consent | Date

APPENDIX C.

USABILITY QUESTIONNAIRE

[Please see the next page]

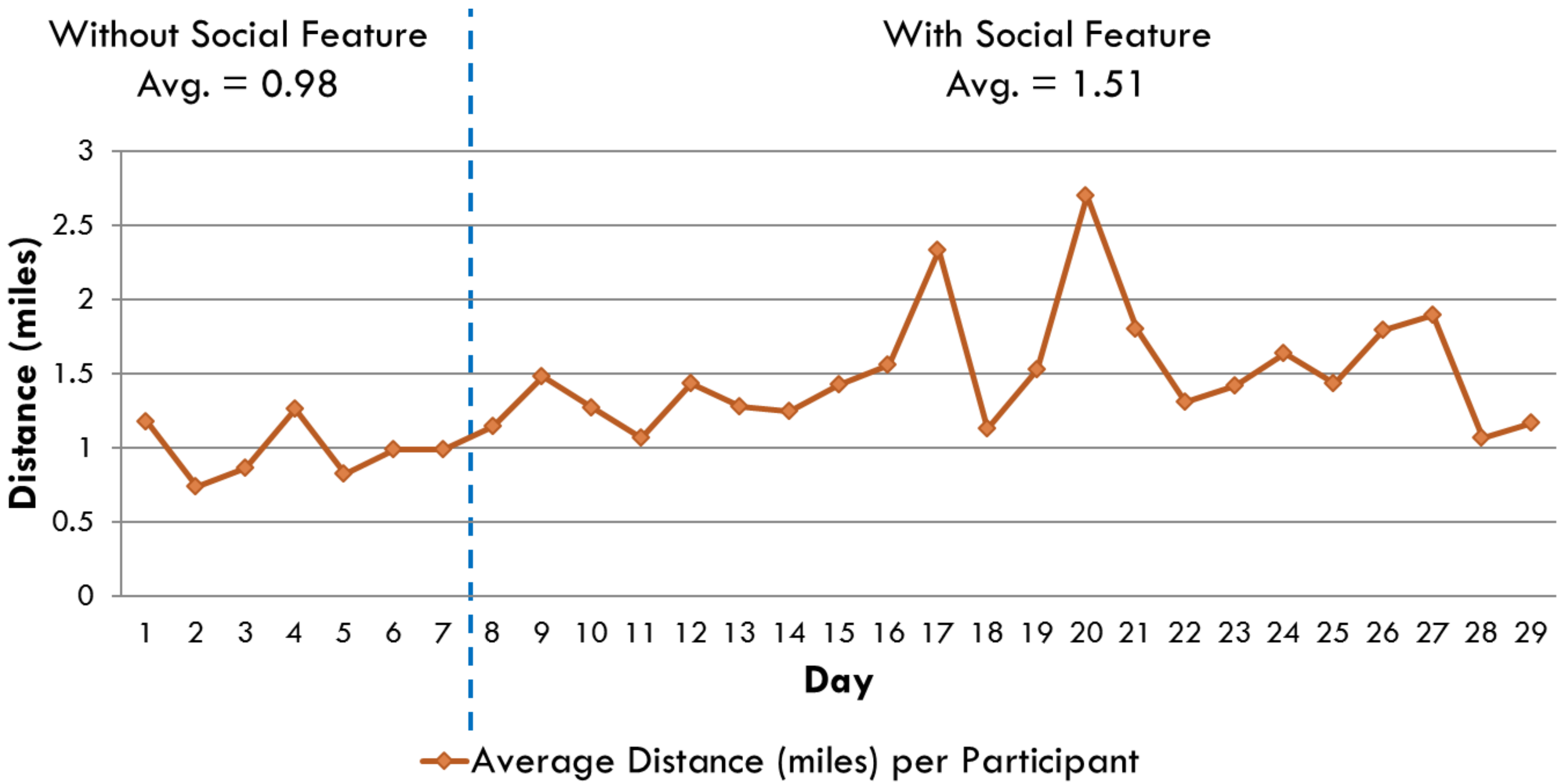
On a scale of 1-5, please circle what number you choose (1 being totally disagree and 5 being totally agree)?

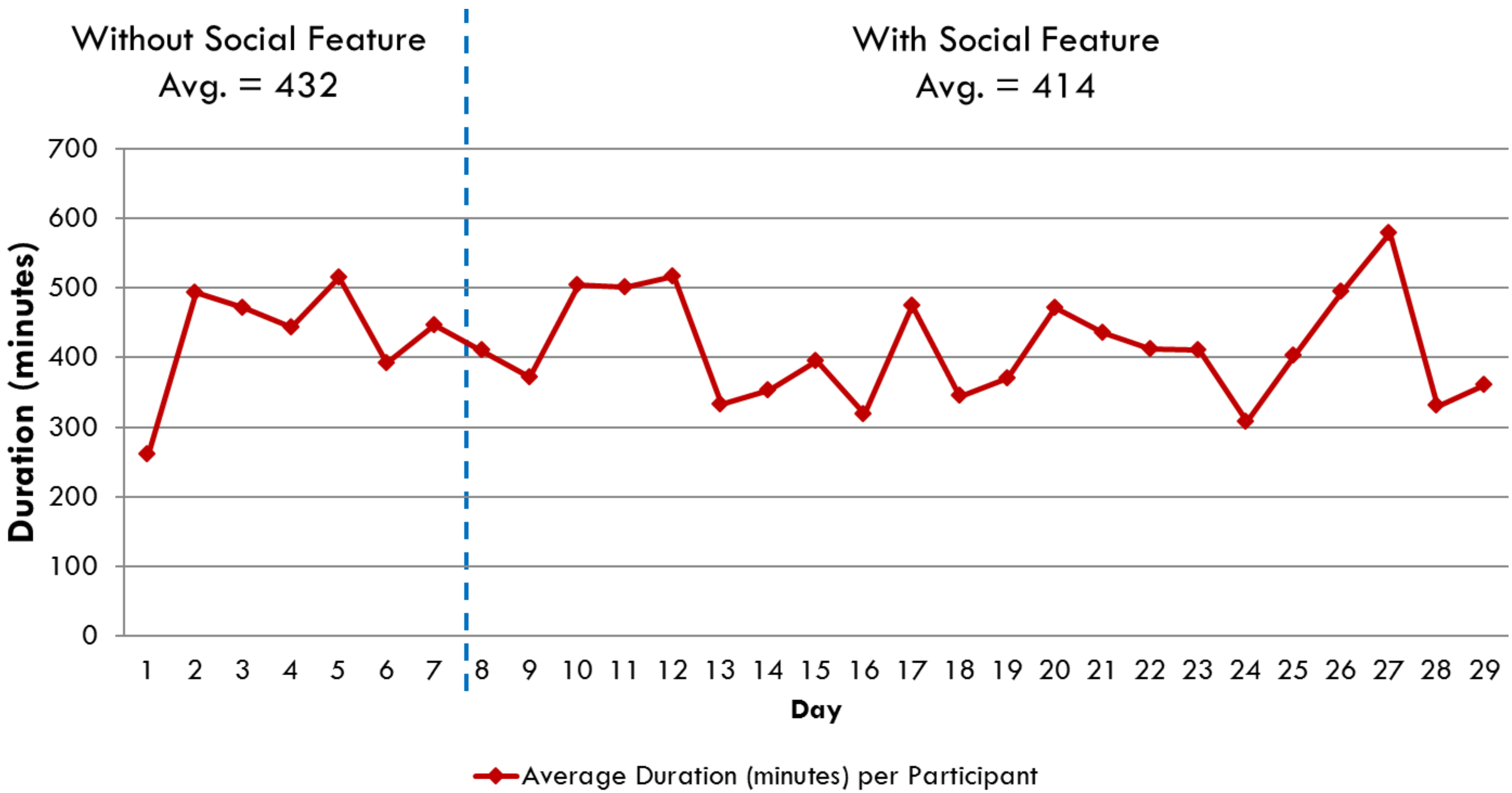
Question	Answer
It was easy to learn how to use this system	1 2 3 4 5
It was easy and simple to use this system	1 2 3 4 5
It was easy to obtain what I need	1 2 3 4 5
The interface of this system is pleasant	1 2 3 4 5
I like the interface of this system	1 2 3 4 5
The organization of information was clear	1 2 3 4 5
It was easy to navigate where to find what I need	1 2 3 4 5
Whenever I made a mistake using the system, I could recover easily and quickly	1 2 3 4 5
The system gave error messages that clearly told me how to fix problems	1 2 3 4 5
This system has all the functions and capabilities I expect it to have	1 2 3 4 5
Overall, I am satisfied with the quality of service/information being provided via this system	1 2 3 4 5

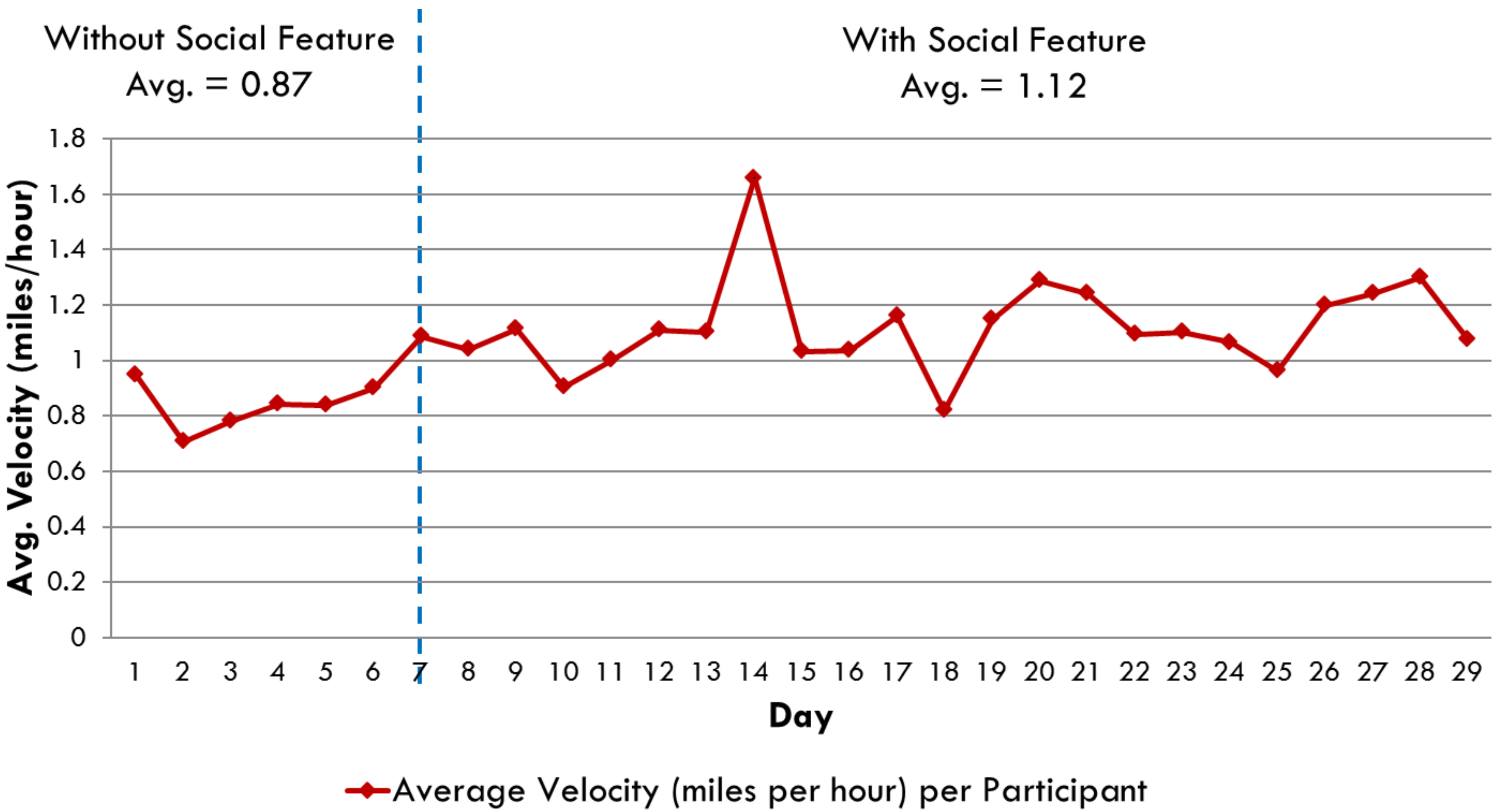
APPENDIX D.

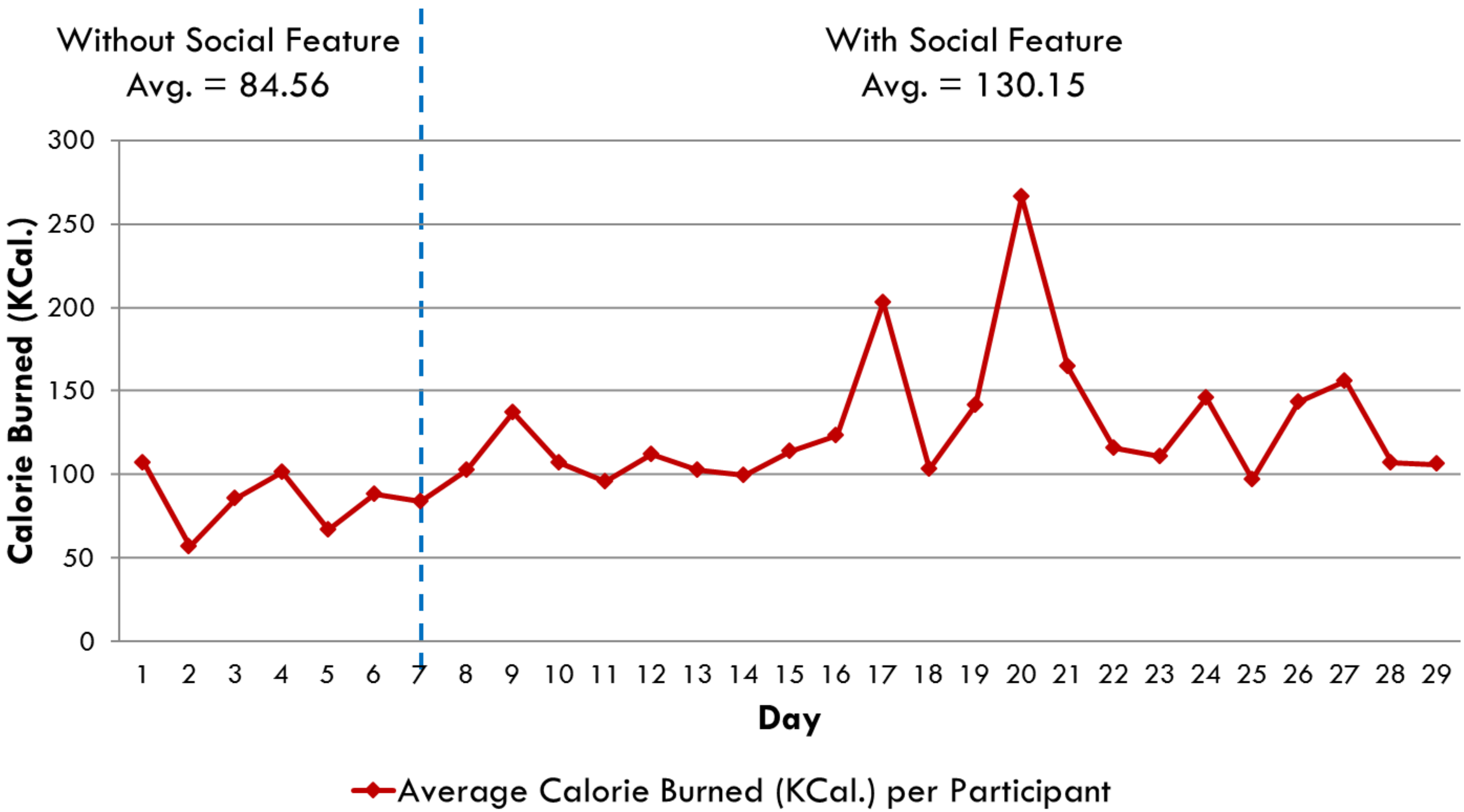
PHYSICAL ACTIVITY DATA

[Please see the next page]


Without Social Feature
Avg. = 0.98
With Social Feature
Avg. = 1.51
Distance (miles)
3
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Day
Average Distance (miles) per Participant


Without Social Feature
Avg. = 432
With Social Feature
Avg. = 414
700
600
500
400
300
200
100
0
Duration (minutes)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Day
Average Duration (minutes) per Participant


Without Social Feature
Avg. = 0.87
With Social Feature
Avg. = 1.12
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Avg. Velocity (miles/hour)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Day
Average Velocity (miles per hour) per Participant



Without Social Feature
Avg. = 84.56
With Social Feature
Avg. = 130.15
Calorie Burned (KCal.)
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Day
Average Calorie Burned (KCal.) per Participant

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