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Discovering Design Principles for Health Behavioral Change Support Systems: A Text Mining Approach

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DISCOVERING DESIGN PRINCIPLES FOR HEALTH BEHAVIORAL CHANGE SUPPORT SYSTEMS: A TEXT MINING APPROACH

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DISSERTATION APPROVAL FORM

This dissertation is approved as a credible and independent investigation by a candidate for the Doctor of Science degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this dissertation does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department or university.

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ABSTRACT

Behavioral Change Support Systems (BCSSs) aim to change users' behavior and lifestyle. The potential outcomes of these systems make them especially important in areas such as healthcare where these systems could be leveraged to persuade users toward healthy behaviors and then achieve their health goals better. In this regard, health BCSSs have been gaining popularity with the proliferation of wearable devices and recent advances in mobile technologies. Recently, with the promising influence of smartphone applications in supporting healthy lifestyle, researchers have been attracted to explore design principles that can encourage on-going and sustainable use of these persuasive systems.

Little research, however, has developed persuasive design principles based on users' feedback collected from User-Generated Contents (UGC) such as online users reviews. Designing effective persuasive systems must be driven by paramount consideration of what the users need. Analyzing users' reviews from the actual use has great potential to inform design of these health consumer technologies through providing developers with valuable insights into users' preferences, experiences and how they interact with these self-care technologies. Therefore, designing a more effective tools that directly meet users' requirements, wishes and needs.

This study extends the existing literature by discovering design principles for health BCSSs based on a systematic analysis of users' feedback. Specifically, this research demonstrates the use of text mining approach to design health BCSSs. That is, the primary objective of this research project is to identify design principles of BCSSs using user-generated content (in terms of apps reviews). Mobile diabetes applications are used as the context of this study. A topic modeling technique is employed to first classify the data (user reviews) into different topics. An existing topic modeling algorithm, Latent Dirichlet Allocation algorithm, is used for classification and identification of various topics. These topics are then mapped into design features which are then grouped into 11 design principles.

The importance of the design principles is demonstrated through analyzing the relationship between the design principles and user ratings. First, the existence of the design principles in users' complaints (i.e., 1- or 2-star reviews) is investigated. Second, the relationship between the number of design principles incorporated in apps and user ratings is explored. Overall, the results highlight the necessity of going beyond the techno-centric approach used in current practice and incorporating the social and organizational (i.e. technical support) features into persuasive system design, as well as integrating users with medical devices such as glucose meter and insulin pump and other systems in their usage context.

DECLARATION

I hereby certify that this project constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the project describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,

__*Mohammad*__________________________

Mohammad Aref Abdel-Rahman

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CHAPTER 1

INTRODUCTION

This chapter presents a detailed discussion on the background of the research problem, the statement of the problem and the objectives of this research. It begins with an in-depth review of the background of the research problem and then discusses the key factors that were critical to the formation of research objectives and then concludes with a high level overview of the structure and flow of this document.

1.1 Background of the Problem

Persuasive systems, also referred to as behavioral change support systems (BCSS), are "a socio-technical information systems with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception" (Oinas-Kukkonen 2013) (p. 1225). This definition includes three potential successful voluntary outcomes for a BCSS: the *formation, alteration or reinforcement of attitudes, behaviors, or complying* (Oinas-Kukkonen 2013). These promising outcomes make BCSSs especially useful in certain areas such as healthcare, where these systems could be leveraged to encourage people toward healthy behavior and then help them to attain their goals better. In fact, BCSSs have demonstrated great potential in contemporary health-related prevention services, applications and products (Chatterjee and Price 2009). Due to its role in fostering improved health and healthier lifestyles, health BCSS is considered nowadays one of the most prominent areas for future healthcare improvements (Oinas-Kukkonen 2013). Indeed, health BCSSs have been reported to produce positive results in areas such as management of smoking cessation, hazardous drinking, obesity, diabetes, asthma, tinnitus, stress, anxiety and depression, complicated grief, and insomnia (Strecher 2007). These technologies can be delivered via Web, SMS, social networking systems, or by other state-of-art technological means such as health interventions available via mobile devices (Oinas-Kukkonen 2013).

1.2 Statement of the Problem

In the last decade, the exponential growth in smartphone technology have resulted in opportunities to encourage and support health care consumers to adopt healthy behaviors and to self-manage chronic diseases. Mobile health interventions have been designed to increase healthy behavior (for example, to increase smoking cessation or activity levels) or improve disease management (for example, by increasing adherence to prescribed medication, or improving management of diabetes) (Free et al. 2013). The features of mobile technologies that may make them particularly appropriate for providing individual level support to health care consumers relate to their popularity and their mobility. Therefore, health-related mobile applications (*usually referred to as apps*) run over smartphones hold promise for healthy behavior change (Yoganathan and Kajanan 2014) and help reduce the risk of long-term disability. Despite its potential benefits and growing popularity, healthcare apps as health persuasive technology still have not been used to their fullest strength. According to (Mclean 2011), 26% of healthcare apps are downloaded with only one use and 74% of them drop out by the tenth use. Only 5% of health apps are still in use 30 days after download (Thomas 2013b). The literature of consumer health IT applications shows that their potential has not yet been realized due to inadequate design. In an exhaustive review of consumer health informatics (CHI) applications, Gibbons et al. (2009) identify design barriers that have prevented the adoption of consumer health IT applications. The barriers identified include not only technological issues such as incompatibility with current care practices, but span issues across social and technical boundaries. Therefore, more research need to be performed to explore the efficacy of healthcare apps as consumers adherence tools. Particularly, it is important to adopt a holistic socio-technical perspective to develop mobile apps for self-care and patient empowerment. In particular, to build successful and sustainable health apps, developers have to bring users into their design so that they can identify flaws and uncover needed workflow and interface functions (Jackson 2011).

Past research on BCSSs has primarily focused on developing theories for predicting user acceptance or adherence of the information technology rather than for providing systematic analysis and design principles for developing these systems (Oinas-Kukkonen and

Harjumaa 2009). For instance, Kelders et al. (2012) reviewed 101 articles on health interventions and demonstrated that intervention characteristics and persuasive design affect adherence to web-based interventions. In a more recent study, El-Gayar et al. (2013c) conducted a systematic review of IT intervention for diabetes self-management and found that IT interventions should rely on principles of user-centered and socio-technical design in its implementation. Such theoretic studies undoubtedly help inform the understanding of behavioral change support technology. However, they seem to be limited with respect to their application to BCSS design and development (Harjumaa and Oinas-Kukkonen 2007).

With respect to studies that aimed at developing design principles for BCSS, Oinas-Kukkonen and Harjumaa (2009) proposed a set of design principles classified into four categories including *primary task support*, *dialogue support*, *system credibility support* and *social support*. However, the proposed design principles appear to be based on experts' intuitions and an analysis of prior research, rather than a systematic analysis of users feedback from the actual use of BCSSs (i.e. the study is conceptual and theory-creating by its nature). Other studies often focus on investigating the effectiveness of persuasive systems design rather than developing design principles for enhancing the effectiveness. In this regard, Harjumaa et al. (2009) explore how persuasive techniques function in real-word settings and the distinct ways in which they influence users. Likewise, Segerståhl et al. (2010) investigated persuasive functionality of a web service targeting weight loss using online questionnaire. More recently, Wildeboer et al. (2016) discovered a correlation between the number of persuasive technology principles and the effectiveness of web-based interventions for mental health. However, this does not always mean that implementing more principles leads to better outcomes. Specific principles seemed to work well together (e.g. tunneling and tailoring; reminders and similarity; social learning and comparison), but adding another principle can diminish the effectiveness (e.g. tunneling, tailoring and reduction). These findings could help developers to decide which persuasive techniques to include to make web-based interventions more persuasive.

However, there are no studies to date that have aimed at discovering design principles by systematically analyzing users' feedback gathered from the electronic word-of-mouth (eWOM). Nowadays, the advances of Web 2.0 technologies have enabled consumers to easily and freely exchange opinions on products and services on an unprecedented scale (volume) and in real time (velocity). Online user review systems provide us with one of the most powerful channels for extracting user feedback that can help enhance persuasive systems design. In the e-commerce domain, users reviews have long been widely recognized as a crucial factor that influences products sales (e.g., Chevalier and Mayzlin 2006) and shapes consumers' purchase intention (e.g., Yang et al. 2016). In the domain of health BCSSs, analyzing users' reviews has the potential to greatly inform developers about how users engage with health BCSSs and opportunities for further enhancing their efficacy. However, up to now, very few efforts have been made to extract knowledge from large-scale online reviews of mobile health apps to help understand consumer satisfaction and its antecedents. Although 72% of mobile health app vendors have used analytics and testing tools to develop, test, market and monitor the performance of their apps (Research2guidance 2016), most mobile health app developers have ignored users' needs by designing tools that primarily reflect the imperatives of clinicians with little or no attention to users' experiences, wishes or requirements (Thomas 2013a).

Therefore, studies that systematically analyze users' reviews and develop design principles from the actual use of BCSSs are needed. Investigating health BCSS's actual use through analyzing user feedback is particularly necessary for persuasive system design since user acceptance/adherence is the central theme of persuasive technology. Actually, health BCSSs cannot help facilitate self-monitoring and self-management or even improve patients' health outcomes when patients do not accept the technology first. Identifying design principles from the actual use of health BCSSs can improve the acceptance first for the technology. Second, it aids in developing health BCSS applications that fulfill patients' needs and expectations. Third, it increases the likelihood of technology implementation success by persuade patients toward better health behaviors.

1.3 Objectives of the Dissertation

This study aims to systematically analyze users' reviews and develop design principles from the actual use of BCSSs. We use *diabetes mobile applications* as instance of health BCSS and develop design principles based on a systematic analysis of users reviews. Diabetes is a chronic illness that requires continuing medical care and ongoing patient self-management education and support to reduce the risk of long-term disability and prevent complications (American Diabetes Association 2016). It is a major public health problem that affected 285 million adults worldwide and accounted for a global health care expenditure of USD376 billion in 2010; and the figures are projected to increase to 439 million adults and USD490 billion by 2030 (Or and Tao 2014). Existing research such as Or and Tao (2014) and El-Gayar et al. (2013b) has proved that the use of health mobile apps improves outcomes in the patient self-management of diabetes. However, the current diabetes mobile apps have failed to achieve their full potential, and they are either too narrow or too technical to become a daily companion for consumers (Research2Guidance 2014). Therefore, in this research, we aim to extract insights from users' reviews of diabetes mobile apps. Given the huge amounts of mobile apps reviews data available online and to facilitate the analysis process, we propose a new method that utilizes text-mining, specifically topic modeling, to automatically analyze the contents of user reviews and discover design principles. With the transformational power of big data analytics, it is now possible to take eWOM data as an important variable in persuasive systems design equation. To evaluate the design principles extracted, we first investigate their existence in users' complaints and second explore the relationship between the number of design principles incorporated in apps and users ratings. Furthermore, we compare our data-grounded design principles with the design principles developed by Oinas-Kukkonen and Harjumaa (2009) as well as other literature related to the acceptance of Consumer health information technology (CHIT).

The main contributions of this study are summarized as follows:

1) From a *theoretical perspective*, the findings of this study inform the design theory of persuasive systems. Specifically, this study develops new persuasive design principles and provides support to some existing theoretical persuasive design principles developed by Oinas-Kukkonen and Harjumaa (2009). Different from current research

that focuses on the technical issues, this research advocates a socio-technical design of BCSSs. We develop design principles that foster the integration and communication between the various components within the ecosystem that is primarily informed by the key beneficiaries of such systems. Moreover, since these design principles extracted from users' feedback that reflect users' preferences are likely to influence users' acceptance of these technology, the study contributes to the literature of users' acceptance of these technology. Last but not least, the findings reveal which of the persuasive design principles are the most effective for mobile-based interventions for diabetes patients. Moreover, we present which of these design principles are most impactful on users' satisfaction.

2) From a *methodological perspective*, this research introduces a new method that leverages text analytics technique to identify design principles from online user-generated content in the health care domain. As far as we know, this is the first work that leverages online user reviews content and topic mining in the field of persuasive systems. The proposed method could also be deployed in other domains to inform pertinent theory based on the wealth of user-generated input made available through user reviews.

3) From a *practical and applied research perspective*, the research further contributes to the fledging persuasive system development industry, particularly with the proliferation of wearable devices. The findings of the study highlight the importance of integrating users with other systems and medical devices in their usage context as well as incorporating the social and technical support features into design. Moreover, the study demonstrates the importance of the design principles discovered through analyzing their appearance in unsatisfying users' experiences (i.e. users complaints), which indicates high impact of them on users' satisfaction. The study also provides developers with insight into the user-reported issues of health apps, along with their frequency, impact and relationship to user ratings. These insights can help developers better prioritize the relevance and application of design principles while designing their apps.

1.4 Structure of the Dissertation

The remainder of the dissertation is structured as follows. In chapter 2, a theoretical background and comprehensive literature review of related work are presented. Chapter 3 argues the research methodology adopted in this dissertation. The design science research methodology is followed and the guidelines of this methodology according to Hevner et al. (2004) are addressed. Chapter 4 presents the design of the text-analytics based approach (which is one of the main design artifacts in this study) used to discover the design principles for health BCSSs and explain the key elements within it. Chapter 5 presents detailed discussion of the results (i.e. the design principles discovered). In this chapter, we compare the design principles identified with existing related literature. Chapter 6 demonstrates and evaluates the design principles proposed in this work. Finally, Chapter 7 concludes the report by presenting an overview of the contributions of this project. The implications and limitations are discussed in this chapter as well as the future directions of this research project.

CHAPTER 2

THEORETICAL BACKGROUND AND PERTINENT LITERATURE REVIEW

First, this chapter discusses the socio-technical design theory as a theoretical background of this research as well as reviewing the behavior change-related theories in Information Systems (IS). Then, the chapter presents an in-depth review of the existing literature pertaining to the health Behavioral Change Support Systems (BCSSs) and impacts of user-generated content. In this regard, it begins with discussing the literature of the design and development of health BCSSs. Second, it sheds the light on the literature of users' acceptance of these consumer health technologies. Last, the effect of user-generated contents (such as reviews and rating systems) in areas like e-commerce and social media is explored.

2.1 Theoretical Background

In this section, a theoretical background of the study is presented. Specifically, following subsections present the socio-technical theory and behavioral change-related theories in Information systems.

2.1.1 Socio-Technical Design

The term socio-technical systems is an integration of two primary concepts, social system and technical system, in which the systems are viewed as the sum of and interplay between the social system and the technical system (Hanssen 2012). The technical system refers to the technology and its associated work structure, while the social system includes individuals along with their grouping into teams as well as the coordination, control and boundary management (Mumford 2006). According to Scacchi (2004) (p. 2), the components of the socio-technical systems are "the network of users, developers, information technology at hand, and the environments in which the system will be used and supported".

Baxter and Sommerville (2011) (p. 4) refer to socio-technical systems design (STSD) methods as "an approach to design that consider human, social and organizational factors, as well as technical factors in the design of organizational systems". In this context, organizational factors refer to company or business related factors while social factors refer to those related to the relationships between people who interact together within and across organizations (Baxter and Sommerville 2011). Overall, the fundamental premise of socio-technical work and system design approaches is the importance of ensuring that the technical and human factors are (whenever possible) given equal weight in the design process, i.e., "the joint optimization of the social and technical systems" (Mumford 2006) (p. 321). Toward this objective, Cherns (1976) identifies nine principles for socio-technical design. Clegg (2000) later presents a revised set of these sociotechnical principles to guide system design, and to consider the potential roles and contributions of such principles. Clegg (2000) categories these revised principles into three types namely Meta, content and process that are highly interrelated. As stated by the author, these principles are to be used by system managers, users, designers, technologists and social scientists (Clegg 2000) . They provide inputs to who are engaged collaboratively in design (El-Gayar et al. 2013a). Table 2.1 shows the list of socio-technical principles. Overall, socio-technical theory represents an important frontier as an effective design tool for new technology so that social and technological systems are jointly optimized (Cooper et al. 1996).

Table 2.1. Principles for Socio-Technical design (Cherns 1976, 1987)

Principle	Description
Principle 1. Compatibility	"The process of design must be compatible with its objectives. If the objective of design is a system capable of self-modification, of adapting to change, and of making the most use of the creative capacities of the individual, then a constructively participative

	organization is needed" (Cherns 1976) (p. 785) Clegg (2000) has addressed principle 1 under the principle that state that "systems and their design should be owned by their managers and users" (p. 465). Under this principle, Clegg (2000) has emphasized on user ownership instead of focusing on user participation like Cherns's principles. (Cherns 1976, 1987) focused on the need for compatibility between process and outcome, and this highlighted the need to involve users in design. The emphasis by Clegg (2000) is on the related "notions of ownership and appropriation, that is with who owns the new system and the processes through which it is designed and implemented" (p. 472).
Principle 2. Minimal critical specifications	Only the minimal critical allocation of critical tasks to jobs, jobs to roles, and objectives Specifications and methods that is absolutely essential should be specified. Systems should allow for some flexibility in their operation (Clegg 2000). According to this principle, the users should be allowed to solve their own problems and develop their own methods of working, thereby incorporating scope for learning and innovation. Such situation is very difficult to achieve in bureaucratic organizations where standard and common working practices may be the norm (Clegg

	2000).
Principle 3. The Socio-Technical criterion/ variance control	Variances (i.e. deviations from expected norms and standards), if they cannot be eliminated, must be controlled as near to their point of origin as possible (Mumford 2006). “Problems of this kind should be solved by the group that experiences them and not by another group such as a supervisory group” (Mumford 2006) (p. 323). Principle 3 is addressed in the same way by Clegg (2000) under the principle called “problems should be controlled at source” (p. 465) where variances (called un-programmed events) should be controlled at source.
Principle 4. The multi-functionality principle	“Work needs a redundancy of functions for adaptability and learning. For groups to be flexible and able to respond to change, they need a variety of skills. These will be more than their day-to-day activities require” (Mumford 2006) (p. 323). Principle 4 has been extended by Clegg (2000) to incorporate consideration of task allocation between humans and machines. Sociotechnical systems consist of allocating tasks to and between humans and machines (Clegg 2000)
Principle 5. Boundary location	“Boundaries should facilitate the sharing of knowledge and experience. They should

	occur where there is a natural discontinuity – time, technology change, etc. – in the work process. Boundaries occur where work activities pass from one group to another and a new set of activities or skills is required. All groups should learn from each other despite the existence of the boundary" (Mumford 2006) (p. 323). Principles 5 and principle 6 are addressed by Clegg (2000) under the "Core processes should be integrated" principle (p. 468) by viewing the organization as comprising a number of core processes that typically cut laterally across different functions, not like the traditional, where it is comprise sets of expertise-based specialisms that are organized vertically.
Principle 6. Information flow	"This principle states that information systems should be designed to provide information in the first place to the point where action on the basis of it will be needed" (Cherns 1976) (p. 789).
Principle 7. Support congruence	"This principle states that systems of social support should be designed so as to reinforce the behaviors which the organization structure is designed to elicit" (Cherns 1976) (p. 790). Principle 7 has been extended by Clegg (2000) by considering that new designs

	involve a set of working arrangements and these needs to be congruent with surrounding systems and practices. These new systems become integrated into existing ones, but such systems may require some accommodation by the systems into which it is being placed (Clegg 2000).
Principle 8. Design and human values	“This principle states that an objective of organizational design should be to provide a high quality of work” (Cherns 1976) (p. 790). Such high quality of work demands “jobs to be reasonably demanding, opportunity to learn, an area of decision-making, social support, the opportunity to relate work to social life, and a job that leads to a desirable future” (Mumford 2006) (p. 323).
Principle 9. Incompletion	This design principle states that the “design is a reiterative process” (Cherns 1976) (p. 791). In essence, new requirements in the work environment needs continual rethinking of structures and objectives of the system, which makes the design never stops (Mumford 2006). Principle 9 has been addressed by Clegg (2000) as the “transitional organization and incompletion” principle (p. 465), where this principle states that systems that undertake design also need designing, and that sociotechnical thinking, ideas and principles

	are applicable to such systems.
Principle 10. Power and authority	"Those who need equipment, materials, or other resources to carry out their responsibilities should have access to them and authority to command them. In return, they accept responsibility for them and for their prudent and economical use. They exercise the power and authority needed to accept responsibility for their performance. But there is also the power and authority that accompanies knowledge and expertise" (Cherns 1987).
Principle 11: Transitional organization	"Those who need equipment, materials, or other resources to carry out their responsibilities should have access to them and authority to command them. In return, they accept responsibility for them and for their prudent and economical use. They exercise the power and authority needed to accept responsibility for their performance. But there is also the power and authority that accompanies knowledge and expertise" (Cherns 1987).

While the aforementioned discussion referred to an organizational context and despite the considerable variation that exists surrounding the term 'socio-technical system' across various fields of study (Baxter and Sommerville 2011), socio-technical perspective could be also applied to the context of information systems. In this regard, a socio-technical system (Figure 2.1) can be modeled as a collection of four components, namely tasks, actors, structure, and technology and their inter-relationships (Leavitts 1964; Lyytinen and Newman 2008). Tasks describe the goals and purpose of the system and the way work/activities is accomplished. Actors refer to users and stakeholders who perform and influence the work/activities. Structure denotes the surrounding project and institutional arrangements while technology refers to tools and interventions used to perform the work/activities. In order to characterize the content of any information system change as well as the engine for that change, the socio-technical theory has been used by Lyytinen and Newman (2008), where the socio-technical components and their connections are considered the general 'lexicon' for describing the information system change.

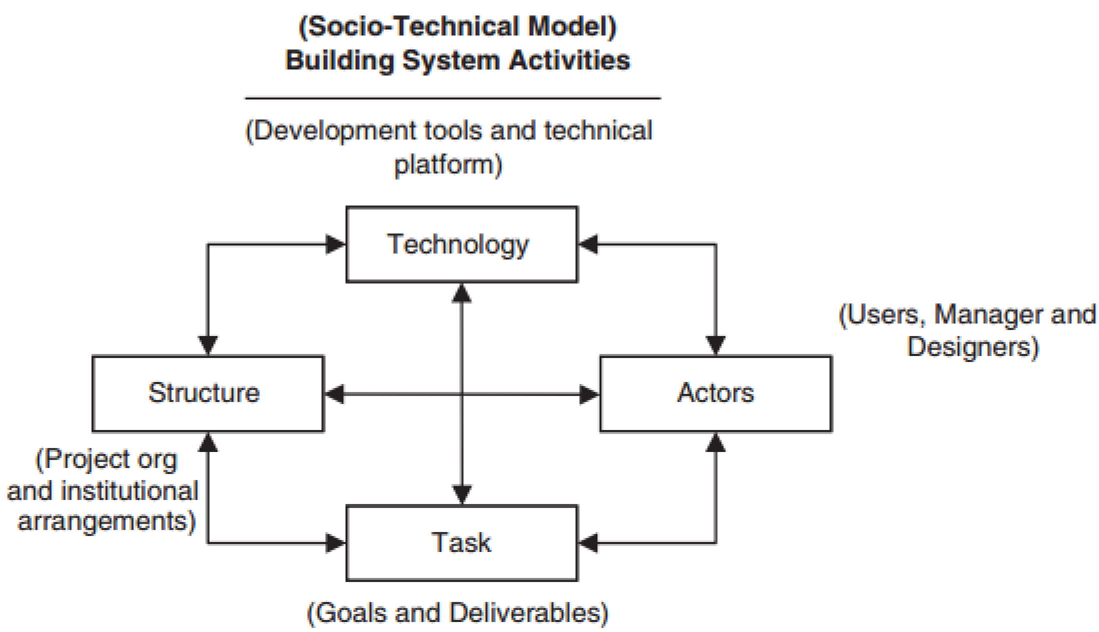

Figure 2.1. Components of a Socio-Technical System (Lyytinen and Newman 2008)

Socio-technical considerations are also applicable to pervasive and ubiquitous systems for self-care, self- management, and patient empowerment (El-Gayar et al. 2013a). Indeed, the design of pervasive computing applications has emerged as a notable research area (Tang et al. 2011). Although significant work has been done in various areas of pervasive computing application design (e.g., Bakhouya 2009; Zhou et al. 2011; Mei and Easterbrook 2007), most research in pervasive systems design is oriented towards technological aspects and is not people focused (El-Gayar et al. 2013a). The key challenge in pervasive systems design is to move the focus from pure technology to contexts of daily life (Thackara 2001). In fact, understanding user task goals, user interactions and capturing appropriate context are some of the open issues that remain in supporting the design of pervasive computing applications. To address these issues, El-Gayar et al. (2013a) investigated the role of socio-technical principles and components in guiding the design of pervasive IT-enabled system for self-care and self-management. In particular, authors identified a new socio-technical model for IT-enabled self-care systems by reviewing relevant literature, coding and categorizing literature findings and relevant self-care concepts along the four socio-technical model components. A summary of the proposed socio-technical model is presented in Table 2.2.

Table 2.2. The Socio-Technical Model for IT Enabled Self-Care Systems (El-Gayar et al. 2013a)

	Work System	**Building System**	**Environment**	**Main Properties**
Task	Medical therapy, lifestyle changes, symptom monitoring etc.	Self-care processes such as self-glucose monitoring, diet and exercise control etc.	Health maintenance and improvement	Complexity (Cognitive), importance to health maintenance, difficulty (resistance to change, unpleasantness, etc.), frequency, and costs.
Actors	Patients and healthy persons	Family, care givers, clinicians, friends, and support groups.	Society and payers	Skills, knowledge, perceived health status, self-efficacy, expectations, beliefs. Social and family support, beliefs and motivation, cognitive function, experience, and knowledge.

Structure	Personal routines within which self-care is embedded	Family and health marketplace structure within which personal routines exists.	Societal and health system structure.	Communication processes, authority, workflows, economics, appropriate and knowledge sources.
Technology	Devices such as pedometers, glucose meters etc.	Home electronic devices and software such as smart phones and personal computers, and health organization IT infrastructure	Societal IT infrastructure	Functionality, interoperability and usability

2.1.2 Behavior Change-Related Theories in Information Systems (IS)

The study of users' attitudes and behavior has a long history in information systems research (Oinas-Kukkonen 2010). Well-known theories related to user attitudes and behaviors include, for example, the Theory of Reasoned Action and the Theory of Planned Behavior. Behavioral researchers have drawn lessons from social psychology and cognitive psychology and new theories such as the Technology Acceptance Model (TAM) and the Unified Theory of Use and Acceptance of Technology (UTAUT) have been developed. In addition to these theories, there are also useful attitude and/or behavior change related theories such as the Self-Efficacy theory, the Social Cognitive Theory, the Elaboration Likelihood Model, the Cognitive Dissonance Theory, and the Goal Setting Theory. Table 2.3 below, which is adopted from Oinas-Kukkonen (2013), provides a summary of behavior change-related theories.

Table 2.3. Behavior change-related theories (Oinas-Kukkonen 2013) (p. 1224)

Theory of reasoned action	Behavioral intentions determine individual behavior, i.e., an individual’s attitude toward the behavior and subjective norms about the behavior (Ajzen and Fishbein 1975)
Theory of planned behavior	Individual’s perception of the ease with which the behavior can be performed affects the individual’s intentions and behaviors, i.e., behavioral control influences individual’s behaviors (Ajzen 1991)
Technology acceptance model (TAM)	An individual’s intention to use a system that in turn leads into actual system use is determined by perceived usefulness and perceived ease of use. Perceived ease of use influences perceived usefulness, supposes that when actors just have an intention to act, they are free to act without limitations, based on theory of reasoned action (Davis 1989)
Unified theory of acceptance and use of technology (UTAUT)	Extension of technology acceptance model. Performance expectancy, effort expectancy, social influence, and facilitating conditions impact the behavioral intention and usage behavior, while experience, gender, age, and voluntariness of use moderate this impact (Venkatesh et al. 2003)
Self-efficacy theory	Individuals who perceive themselves as able of completing task also do complete task; reinforcement the sense of efficacy may occur through various ways such as vicarious experiences, social models, social persuasion, as well as

	reducing people's stress reactions and altering their negative emotional tendencies and misinterpretations of their physical states (Bandura 1977, 1994)
Social cognitive theory	Observing others performing a behavior effects individual's perception of his/her own ability to perform the behavior, i.e., self-efficacy, and the perceived expected outcomes (Bandura 1986)
Elaboration likelihood model	Central and peripheral routes are two primary routes for persuasion; The central route means that individuals use high cognitive effort (i.e. critical thinking) to elaborate information, whereas the peripheral one indicates that individuals adopt heuristics and simple decision rules to quickly form judgments. Change via central route is more enduring, resistant and predictive of behavior (Petty and Cacioppo 1986)
Cognitive dissonance theory	Individuals aim consistency among their cognitions such as attitudes and opinions; inconsistency between believes and behaviors develops dissonance that needs to be removed (Festinger 1957)
Goal setting theory	Goals influence performance through directing attention and effort, energizing, persistence, and by leading to arousal and/or use of task-relevant knowledge and strategies; the highest goals lead to the highest levels of effort and performance; specific, difficult goals consistently lead to higher performance than urging people to do their best;

	when goals are self-set, people with high self-efficacy set higher goals than people with lower self-efficacy; people with high self-efficacy are more committed to the assigned goals and to responding more positively to negative feedback (Locke and Latham 2002)
Computer self-efficacy	Computer self-efficacy refers to individual's judgment of one's capabilities to use computers for both task performance and computer performance; anxiety, innovativeness, task characteristics, prior performance, and perceived effort play a role, based on self-efficacy theory (Compeau and Higgins 1995)

2.2 Pertinent Literature Review

In this section, the pertinent literature is discussed. In particular, three streams of related research are reviewed. First, literature pertaining to Health Behavioral Change Support Systems (BCSSs) Design. Second, literature of Acceptance of these consumer health technologies. Finally, the stream of literature of the effects of user-generated content (such as online users reviews) is explored.

2.2.1 Health Behavioral Change Support Systems (BCSSs) Design

Since the BCSSs are considered a socio-technical information systems, the design process of these technologies should be understood as the development of sociotechnical configurations (Berg et al. 1998). Therefore, the sociotechnical design method has also been applied to the area of persuasive systems. However, the weakness of the principles for Socio-Technical design mentioned above is that they cannot be easily transformed into software requirements and further implemented as actual system features of persuasive systems. To address this issue and toward providing a precise software qualities and requirements of persuasive systems, Oinas-Kukkonen and Harjumaa (2009)'s study, which is probably the most important study that develops design principles for persuasive systems, presents a framework for Persuasive Systems Design (PSD). The framework incorporates a process of designing and evaluating persuasive systems as well as 28 design principles related to the content and functionality of persuasive systems. Those design principles are categorized into four main groups: *primary task principles* that help carry out users' primary tasks, *dialogue principles* that support the interactivity with users, *credibility principles* to increase the credibility of systems, and *social principles* that leverage social influence to persuade users. However, the proposed design principles appear to be based on existing theories and experts' intuitions rather than analysis of the actual use of persuasive systems (i.e. their study is conceptual and theory-creating by its nature). Moreover, little is known about the effectiveness of these persuasive principles in the context of mobile-based interventions and how users perceive or experience these design principles.

Instead of developing design principles for enhancing the effectiveness, other researchers recently start to focus on exploring the effectiveness of the Persuasive Systems Design (PSD) model. In this respect, Torning and Oinas-Kukkonen (2009) conducted a systematic review of the papers published at the first three international conferences on persuasive technology. The analysis results revealed that tailoring, tunneling, reduction and social comparison are the most studied methods for persuasion. More recently, Wildeboer et al. (2016) found a relationship between the number and combinations of persuasive technology principles and the effectiveness in web-based interventions. Likewise, Karppinen et al. (2016) investigated how users perceived persuasive features in a web-based lifestyle intervention system. The results indicated self-monitoring, reminders, and tunneling were perceived as especially beneficial persuasive features. In another study and to inform the development of a web-based application integrated with the primary care electronic health record, Neubeck et al. (2016) adopted a collaborative user-centered design process to develop a consumer-focused e-health tool for cardiovascular disease risk reduction. In the same context, Kuipers et al. (2016) explores the design of a health BCSS to support education and training for lifting and transfer techniques (LTTs).

With the exponential growth of the communications technologies that allow us to potentially reach more individuals regardless of their locations, new type of health intervention emerged. Smartphone or mobile-based intervention can deliver health BCSSs at a very low cost. Due to the promising influence of these smartphone-based technologies in supporting healthy lifestyle and self-care practices, researchers have been attracted to explore design principles that can encourage on-going and sustainable use of these persuasive systems. For example, Chomutare et al. (2011) studied the design features of mobile applications for diabetes care, in contrast to clinical guideline recommendations for diabetes self-management. The primary finding is that personalized education, which is strongly recommended by clinical guidelines, is not integrated in the current applications. They also found that the integration of mobile applications with social media is missing in most of the current apps. In a more recent study, Langrial et al. (2012) evaluated the persuasive software features assimilated in twelve selected well-being mobile apps using the Persuasive Systems Design (PSD) model proposed by Oinas-Kukkonen and Harjumaa (2009). The study indicates that the current mobile apps often lack features related to human-computer dialogue and social support. Recently, Yoganathan and Kajanan (2013) drew upon persuasive technology design principles embedded in social cognitive theory and developed a conceptual design model of successful fitness apps. They manually coded the apps descriptions to assess the presence of the studied design features and proved that social cognitive theory can be effectively used in the design of successful fitness apps. In a current study, Geuens et al. (2016) evaluated the number and type of persuasive principles present in current health apps for Chronic Arthritis (CA). Specifically, the authors coded 28 apps according to 37 persuasive principles using persuasive system design classification of Oinas-Kukkonen and Harjuma (2009) and the classification of behavior change techniques of Abraham and Michie (2008). They conclude that current health apps for CA patients would benefit from adding Social Support techniques (e.g., social media) and extending Dialogue Support techniques (e.g., rewards, praise). Also, the addition of automated tracking of health-related parameters (e.g., physical activity, step count) could further reduce the effort for CA patients to manage their disease and thus increase Task Support. Finally, apps for health could take advantage of a more evidence-based approach, both in developing the app as well as ensuring that content can be verified as scientifically proven, which will result in enhanced System Credibility. In another current study, Matthews et al. (2016) conducted a systematic reviews for the current state of mobile applications for health behavioral change with an emphasis on applications that promote physical activity. They evaluated the persuasive design features of mobile applications against the Persuasive Systems Design model. The results revealed that primary task support, dialogue support, and social support are moderately represented while system credibility support is less represented in the selected articles.

However, in literature, little is known about how users use and experience mobile applications as health behavioral change support systems and what are the enabling design factors and design barriers to effective use of such applications. Toward addressing this gap, Laurie and Blandford (2016) investigated how users adopt and experience a mobile-based wellbeing intervention. They concluded such systems should be designed with consideration of people's beliefs and lifestyle, and should be flexible to meet the needs of different users. In essence, designers should incorporate features in the design of these applications that manage expectations about use and that support users to fit app use into a busy lifestyle. Further, they found the Reasoned Action Approach is a useful theory to inform future research and design of persuasive mental wellbeing technologies.

Little research, however, has developed persuasive design principles based on user feedback. Designing effective persuasive systems must be driven by paramount consideration of what the users need. After all, user acceptance/adherence is the key to the success of health BCSSs. These technologies cannot help facilitate self-monitoring and self-management or improve patients' health outcomes when patients do not accept them. Moreover, investigating users feedback from the actual use of these systems helps to get insights regarding how users use and experience such applications and what are the design features that may lead to effective use. To address this "gap" in existing research, this research aims to use a text mining approach to automatically identify design features from online user reviews and then develop design principles for health BCSSs based on the discovered features.

2.2.2 Literature of Acceptance of Health Behavioral Change Support Systems (BCSSs)

Another stream of research that this study relates to is users' acceptance of consumer health technology. Table 2.4, which is adopted from Lehto et al. (2013) provides an overview of concepts related to health BCSSs found in the literature.

Table 2.4. Concepts related to BCSSs (Lehto et al. 2013)

Study	Concept	Definition
Eysenbach (2000)	Consumer health informatics	"Consumer health informatics is the branch of medical informatics that analyses consumers' needs for information; studies and implements methods of making information accessible to consumers; and models and integrates consumers' preferences into medical information systems."
Gustafson et al. (2002)	Consumer health informatics systems (CHIS)	"Consumer health informatics systems (CHIS) include patient-oriented interactive computer-based programs that provide information, decision, behavior change and emotional support for health issues."
Murray et al. (2005)	Interactive health communication applications (IHCAs).	"Interactive health communication applications (IHCAs) are computer- based, usually web-based, information packages for patients that combine health information with at least one of social support, decision support, or behavior change support."
Barak et al. (2009)	Web-based intervention	"A primarily self-guided intervention program that is executed by means of a prescriptive online program operated through a website and used by consumers seeking health- and mental-health related assistance. The

		intervention program itself attempts to create positive change and or improve/enhance knowledge, awareness, and understanding via the provision of sound health-related material and use of interactive web-based components.”
Or and Karsh (2009)	Consumer health information technology (CHIT)	“CHITs are defined as computer-based systems that are designed to facilitate information access and exchange, enhance decision making, provide social and emotional support, and help behavior changes that promote health and well-being.”

Although using health BCSSs enhances patients’ self-care and provide cost-effective health intervention tools, these technologies are still not always accepted by patients (Or and Karsh 2009). Indeed, the research into healthcare information and management systems thus far has mostly focused on electronic medical records and health information libraries with less attention to tools for patients’ behavioral change (Oinas-Kukkonen 2013). In fact, a systematic literature review of research regarding patient acceptance of Consumer Health Information Technology (CHIT) conducted by Or and Karsh (2009) revealed that few studies tested the impact of *organizational*, *environmental* or *social factors* on acceptance. These have all received empirical support in literature outside of consumer health informatics, and there are reasons to assume they would be important in CHIT as well. With respect to organizational factors, literature suggests there may be other important *organizational variables* to examine such as *technical support*. It refers to technical help provided by the system developers upon request. Technical support has received empirical support in literature outside of consumer health informatics and there are reasons to hypothesize that it would be also important in CHIT (Or and Karsh 2009). Actually, Karppinen et al. (2014) have recently found that technical issues are important factor for BCSS acceptance.

With regard to environmental factors, only one variable was examined (i.e., patient location when using the technology). Additional environmental factors that refer to the physical aspects of the environment where the patient interacts with the technology should be taken into account in future research. Environmental factors are crucial because they will impede or facilitate individuals' abilities to use technology effectively and efficiently, which in turn can influence technology acceptance of the individual (Or and Karsh 2009).

Lastly, *social factors* were not examined in any study reviewed (Or and Karsh 2009). Or et al. (2011) suggest that perceived usefulness and perceived ease of use have a significant impact on patients' acceptance of web-based self-management technology. Lehto et al. (2012) find that the primary task support (i.e. self-monitoring and persuasive messages) has a positive impact on the perceived persuasiveness which in turn influence users' adoption of virtual health coaching. Ruland et al. (2013) demonstrates the importance of the social forum component in illness management support system for cancer patients. In a more recent study, Karppinen et al. (2014) find that technical issues are important for users' acceptance of eHealth coaching systems. In the following Table 2.5, we summarizes the findings of the recent literature related to identify variables promoting health BCSSs use and acceptance among users.

Table 2.5. Literature of health BCSSs acceptance

Study	**Health BCSS type/Objective**	**Data source/ Analysis method**	**Key findings/Acceptance factors**
(Ruland et al. 2013)	• Illness management support system for cancer patients. • To better understand what components were most helpful.	• Questionnaires asking about reasons for using the different components and their usefulness.	• **Social** factors: The *forum* where patients can communicate with each other and asking questions to the nurse were used the most.
(Karppinen et al. 2014)	• The eHealth check and eHealth coaching.	• Online survey. • Hermeneutics	• **Human-technology interaction** factors:

	• To identify the anomalies related to consumers' non-adoption of a BCSS.	to analyze the open-ended responses.	*Usefulness*, *credibility*, *usability* and *technical issues* of the system are important for BCSS acceptance.
(Or et al. 2011)	• A web-based interactive self-management system. • To determine what predicts patient's acceptance of the system	• Questionnaire.	The following factors predict most of the variance in patients' acceptance • **Social** factor**:** *Subjective norms* • **Human-technology interaction** factors: *Perceived usefulness*, and *perceived ease of use.* • **Patient** factors: *health care knowledge*.
(Lehto et al. 2012)	• Virtual health check • To test factors affecting perceived persuasiveness of the system and whether perceived persuasiveness predicts to adopt the system	• Online survey. • PLS.	• **Human-technology interaction factors**: *Dialogue support*, *primary task support*, *perceived credibility*, and *perceived persuasiveness*.
Technology acceptance for elderly patients/Telehealth systems			
(Peek et al. 2014)	• Electronic technologies that support aging in place.	• A systematic review.	**Pre-implementation stage** • **Patient factors:** *concerns regarding technology*, *expected benefits of*

	• To investigate factors that influence the intention to use or the actual use of electronic technology for aging in place.		*technology, need for technology, alternatives to technology* and *characteristics of older adults.* • **Social** factor**:** *Social influence.*
(Singh et al. 2010)	• To provide a taxonomy of usability requirements and design concepts for home telehealth systems.	• A systematic review to evaluate existing telehealth systems.	• **Human-technology interaction factors**: *functionality* (natural output, Multilanguage support, reminders, reduced computer anxiety, and customized to self-efficacy), *understandability* (mental model, guided instructions), *Interface design (*readability, more pictures than words, appropriate use of colors, and clear screen transitions*), reduced complexity* (easy data entry, simplified tasks), and *feedback* (feedback on health status, graphical representation of health status). • **Organizational factors:** *tailored training program, adequate technical support.* • **Environmental factors:**

			active user participation, multi-user support, face-to-face communication. • **Social** factor**:** *Social support*
(Cimperman et al. 2013)	• Home telemedicine services (HTS). • To examine factors that may predict the successful adoption of HTS.	• Focus groups.	• **Human-technology interaction factors**: *perceived usefulness* and *effort expectancy*. • **Social factors:** *social influence and physician opinion.* • **Organizational factors:** *facilitating conditions* (cost and technical support).
(Or and Karsh 2009)	• To examine factors that determine patient CHIT acceptance based on the empirical findings in the literature.	• A systematic review.	• **Human-technology interaction factors**: *perceived usefulness, perceived ease of use* and *computer anxiety*. • **Patient factors:** *Age, education***,** *prior experience.* • **Organizational factors:** such as *being less satisfied with medical care services* and *being less satisfied with one's health plan.* • **Environmental factors:** *patient location.*

- **Social factors:** *social support*
- **Task factors:**

Also, Table 2.6 summarizes the key findings of the literature regarding the influence of health persuasive systems functionality and techniques on users using data collected from real users.

Table 2.6. Literature of the influence of health BCSSs functionality and techniques on users

Study	Health BCSS type	Data source/ Analysis method	Key Findings
Harjumaa et al. (2009)	• Heart rate monitor. • Examine how a training program in a new prototype heart rate monitor promotes proper exercising.	• Group interviews, participant diaries and observation. • Qualitative data analysis techniques (interpretative content analysis).	The most motivating features of the training program were: • The weekly goals set by the training program. • The tracking performance during and after exercising. • The tracking on a weekly basis. • The adoption of a social role.
Segerståhl et al. (2010)	• A Web service of weight loss. • Discover possible situation in which persuasive	• Online questionnaire. • Interpretative content methods.	The techniques that authors found are especially vulnerable to pitfalls are: 1) Self-monitoring: was clearly hindered by the complexity of reporting (i.e. logging information). The way reporting was carried out with the service was excessively

techniques do not function as expected.

burdensome in the sense that the task required too many steps and cognitive effort from the users.

2) Suggestions: the main pitfall was the misfit between suggestions offered by the system and the actual context of using the service (i.e. the lack of tailoring).

Recommendations:

- The actual use context and routines of everyday life should be recognized and suggestions, at their best, are tailored to match these.
- Personal differences should be also realized when tailoring suggestions.
- The suggestions should be up-dated or fit the context of the calendar year.

3) Social facilitation:

Recommendations:

- The socially constructed content should be tailored and presented to users based on their profiles, goals, and interests.
- Blogs and discussion forums should be easy to navigate and use (i.e. usability) as well as their

			content include expert sourcing and is up-to-date.
Graml et al. (2011)	• Residual energy conservation. • Assess which socio-psychological concepts are best suited to stimulate residual energy conservation in a large scale and real-world setting.	• Usage data and experiments. • Usage data analysis.	Guidelines: • Influence the evaluation of perceived benefits through giving rewards. • Use tailored emotional communication to motivate different user groups. • Provide specific and hard to reach goals. • Use descriptive feedback only in combination with injunctive feedback. • Use public commitment to keep the motivation high. • Guide the user with how-to instructions. • Support repeated behavior with prompts and reminders. • Learning by doing through immediate feedback. • Simplify actions and personalize behaviors.

More research is needed to identify design features that may drive acceptance of these technologies. Examples include further research regarding the role of technical support, social factors, and structural aspects such as the integration with the healthcare system (as noted in Sarnikar et al. (2014)).

2.2.3 The Impacts of User-Generated Content

Several researchers in the areas of social media and e-commerce have studied the effects of user-generated content such as online users' reviews and rating systems on product sales and consumers' purchase intention. The findings of the existing research have demonstrated that analyzing and measuring these electronic word-of-mouth (eWOM) messages is quite valuable in product design, sales prediction, marketing strategy, and other decision-making tasks (see Table 2.7 below). However, to our knowledge, no research to date has looked at online users reviews in the context of health behavioral change support systems (HBCSS). User reviews implicitly communicate satisfaction/dissatisfaction based on actual usage experience and may provide a good opportunity for extracting design dimensions that can strongly influence users' satisfaction and then informing the design of these systems.

Table 2.7. Previous empirical research related to the impact of user-generated content

Author(s)	Research Context and method	Chief purposes	Major findings
		E-commerce context-products sales	
(Chevalier and Mayzlin 2006)	• Book data from Amazon.com and Barnesandnoble.com • Regression.	• To examine the effect of consumer reviews on relative sales of books.	• An improvement in a book's reviews leads to an increase in relative sales at that site. • The impact of one-star reviews is greater than the impact of five-star reviews.
(Ghose and Ipeirotis 2011)	• A panel data set of three products categories (audio and video players, digital cameras, and DVDs).	• To examine the impact of reviews on economic outcomes like product sales.	• The extent of subjectivity, informativeness, readability, and linguistic correctness in reviews matters in influencing sales and perceived usefulness.

	• Econometric, text mining, and predictive modeling techniques.		
(Archak et al. 2011)	• Data set from Amazon containing sales data and consumer review data for two different groups of products. • Text mining.	• To examine the impact of textual content of product reviews on consumers' choices.	• Demonstrates how textual data can be used to learn consumers' relative preferences for different product features and also how text can be used for predictive modeling of future changes in sales.
(Goh et al. 2013)	• Qualitative user-marketer interaction content data from a fan page brand community on Facebook and consumer transactions data. • Text mining and econometric modeling	• To explore the impact of user-generated content (UGC), and marketer-generated content (MGC), on consumers' apparel purchase expenditures.	• Social media contents have impacts on consumer purchase behavior through embedded information and persuasion. • User-generated content (UGC) exhibits a stronger impact than marketer-generated content (MGC) on consumer purchase behavior.
(Zhang et al. 2013)	• Digital camera dataset from Amazon.com. • Network analysis and text sentiment	• Integrating network analysis with text sentiment mining techniques to propose product	• WOM in social media constitutes a competitive landscape for firms to understand and manipulate.

	mining techniques	comparison networks as a novel construct, computed from consumer product reviews.	
(Hu et al. 2014)	• A panel of book dataset from Amazon.com. • Multiple equation model.	• What is the differential impact of sentiments and ratings on sales?	• Sentiments have a direct significant impact on sales. • Ratings do not have a significant direct impact on sales but have an indirect impact through sentiments
(Dewan and Ramaprasad 2014)	• A panel of blog buzz, radio play, and music sales • The panel vector autoregression (PVAR)	• To explore the relationship between new media, old media, and sales in the context of the music industry.	• Sales displacement due to free online sampling dominates any positive word-of-mouth effects of song buzz on sales.
(Liang et al. 2015)	• Seventy-nine paid and seventy free apps from an iOS app store. • Sentiments and econometric analysis.	• To examine the effect of textual consumer reviews on the sales of mobile apps.	• Consumers’ comments on service quality have a stronger unit effect on sales rankings than comments regarding product quality.
(Yang et al. 2016)	• Quasi-experimental design (capture the real patterns of	• To examine the effect of social consensus in	• By impacting buyers’ risk perception and shaping their attitude, online

	online reviews in e-Commerce) and online questionnaires.	product reviews, represented by review balance and volume, on online shoppers' risk perception, uncertainty, attitude and subsequent purchase intention.	reviews, especially negatively distributed reviews, play important role in determining buyers' purchase intention.
Hospitality context-hotels and restaurants			
(Kim et al. 2015)	• Hotel performance data and online review data. • Multiple regression analyses using SPSS 20	• To investigate how managing online reviews affects hotel performance.	• The better the overall ratings and the higher the response rate to negative comments, the higher the hotel performance.
(Xiang et al. 2015)	• Consumer reviews extracted from Expedia.com	• To apply a text analytical approach to a large quantity of user-generated content to deconstruct hotel guest experience and examine its association with satisfaction ratings.	• Results indicate several dimensions of guest experience associated with varying weights. • There is a strong association between guest experience and satisfaction.
(Duan et al. 2016)	• Online user reviews for hotels. • Sentiment and	• To examine the impact of online users reviews on	• Different dimensions of users reviews have significantly different

	econometric analysis	users' overall evaluation and content-generating behavior.	influences in shaping user evaluation and driving content generation.
(Phillips et al. 2016)	• Swiss country-level data for online reviews and data from 442 hotels. • Partial least squares path modelling	• To investigate the impact of online reviews on hotel performance.	• Hotel attributes, including the quality of rooms, Internet provision and building show the highest impact on hotel performance. • Positive comments have the highest impact on customer demand.
(Kim et al. 2016)	• Restaurant performance (internal operational metrics and interviews) and number of reviews, overall rating, regional ranking, and excellence certificates.	• To explore the impact of social media reviews and operating efficiency metrics on restaurant financial performance and to examine the moderating role of an excellence certificate.	• The number of online reviews customers make has a significant positive impact on restaurant performance.
(Guo et al. 2017)	• Online reviews for hotels located in 16 countries. • Latent dirichlet	• Identify the key dimensions of customer service voiced by hotel	• LDA discovers 19 controllable dimensions that are key for hotels to manage their interactions

	analysis (LDA)	visitors using a data mining approach.	with visitors.
Finance context-stock market			
(Aggarwal et al. 2012)	• Ventures information from VentureXpert database and the blog coverage data from Google Blogsearch. • Econometric analysis.	• To investigate the effect of eWOM on venture capital financing.	• The impact of negative eWOM is greater than the impact of positive eWOM and that the effect of eWOM on financing decreases with the progress through the financing stages. • The eWOM of popular bloggers helps ventures in getting higher funding amounts and valuations.
(Yu et al. 2013)	• Financial-statement and financial-market data for a number of companies, and blog, forum, news, and Twitter content related to the company • Sentiment analysis.	• Explore the effect of the social and traditional media on short term stock market performance, and their relative importance and interrelatedness.	• Overall social media has a stronger relationship with firm stock performance than conventional media.
Health context			
(Jung et al. 2015)	• User-generated content from online communities hosted	• To propose a novel approach (text mining) to identify	• Identification of six types of quality factors feasible for social media–based

	by Korean Web portals. • Dictionary-based text mining technique.	hospital service quality factors and overtime trends automatically from online health communities.	hospital service quality analysis.
(Xu et al. 2016)	• Online doctors' appointments made over a five-month period, along with other online information. • Machine learning and structural modeling techniques.	• To examine the impact of online information on patient choice of outpatient care doctors.	• Various operational factors, such as location flexibility, online appointment book, service time, and waiting time have impact on demand.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter argues the design science research methodology adopted in this dissertation, along with the design artifacts, following the guidelines proposed by Hevner et al. (2004). Each of these guidelines is discussed below in the context of this study.

3.1 Design Science Research Methodology

The main difference between the routine information system design and design science research is that design science research generates interesting and new knowledge which contribute to the Information Systems (IS) community. This new knowledge is represented in the new algorithm or method associated with the IT artifact (Hevner et al. 2004).

Design science research aims to create artifacts that include valuable prescriptions help in achieving human goals and improve the efficiency. The products of design science research are constructs, innovative models, methods, and implementation. It includes two basic processes, building and evaluation. Building is the process of creating the artifact for specific task and evaluation is the process of testing it to determine whether the artifact performs the required task or not (Hevner et al. 2004).

Substantial difficulties in design science result from the fact that artifact performance is related to the environment in which it operates. Thus, the main challenge in the design science research is to make sure that the artifact will work properly in the environment in which it operates. Incomplete understanding of that environment can result in inappropriately designed artifacts or artifacts that result in undesirable side-effects. That requires the researcher to thoroughly understand the intended use of the artifact and the environment conditions in which it will operate. In the design science, the objective is achieved when the old technologies are replaced with new more efficient ones (Hevner et al. 2004).

3.1.1 Design as an Artifact

The key design artifacts developed in this dissertation are as follow. First, building upon existing knowledge of descriptive analytics (i.e. unsupervised learning), this research proposes artifact in the form of a "method". In particular, this work first introduces a new method that utilizes text analytics technique, topic modeling, to automatically analyze and extract valuable knowledge (i.e. design features) from online users-generated contents (UGC) such as online users reviews. Second, this research develops new design principles for persuasive systems as well as provides empirical evidence of some exiting theoretical design principles. Both artifacts are discussed in details in chapter 4.

3.1.2 Problem Relevance

The objective of design-science research is to develop technology-based solutions to important and relevant business problems (Hevner et al. 2004). In this regard, this research project analyzes an interesting and relevant problem from the perspective of practitioners. Discovering design principles for health behavior change support systems such as self-care apps is timely and relevant as smart devices are becoming ubiquitous. In essence, the design principles proposed in this project can help mobile apps developers develop more efficient and successful diabetes apps that promote user self-efficacy and sustainable use. Moreover, this work contributes to existing knowledge base of persuasive systems design by 1) supporting some existing theoretical persuasive systems design principles and 2) deducing new design principles.

3.1.3 Design Evaluation

To demonstrate the efficacy and quality of a design artifact, rigorous evaluation methods need to be developed to validate the artifact (Hevner et al. 2004). In this research project, the efficiency of the design artifact, design principles identified, is rigorously demonstrated via exploring the relationship between the design principles and user ratings through conducting two empirical studies. First, the relationship between the design principles and users' complaints (i.e., 1- or 2-star reviews) is examined. Second, the positive relationship between the number of design principles incorporated in apps and user ratings is proved. Further, the design principles are compared with pertinent literature of the persuasive systems design and literature of consumer health information technology acceptance.

3.1.4 Research Contributions

Design science research must generate clear and verifiable contributions in terms to design artifact, foundations and methodologies (Hevner et al. 2004). As stated in chapter 1 (contribution section), the contributions of this research are clear and valid. For instance, the proposed method provides an effective approach to discover design principles for persuasive systems from online user-generated content in the health care context. The suggested approach could also be extended to other domains that share some characteristics of persuasive systems. Further, the proposed method can also help developers to measure the performance of their current apps as well as competing ones.

3.1.5 Research Rigor

Design science research requires adoption of rigorous methods in both the construction and evaluation of the design artifact (Hevner et al. 2004). Regarding the construction of the artifact, this research draws upon existing knowledge base to create the two artifacts. First, the study build upon knowledge base of text mining and descriptive analytics, topic modeling, to propose the new method to discover design features from online users reviews. Second, the work relies on pertaining literature to develop the design principles. With respect to the evaluation, the research adopts rigorous evaluation methods to demonstrate the efficiency of the design principles identified.

3.1.6 Design as a Search Process

According to Hevner et al. (2004), the objective of design science research is to search for the best or optimal design, which makes design science inherently iterative. In this regard, an iterative design strategy is closely adopted in this study to develop the design principles from the topics extracted from user-generated contents. The final design principles (main design artifact in this research) have evolved iteratively by making comparison to the earlier designs and with existing theoretical design principles in pertinent literature.

3.1.7 Communication of Research

The last guideline requires design science research to be presented in a way that is understandable for both technology-oriented as well as management-oriented audiences (Hevner et al. 2004). To ensure this point, this research project is written in a way that makes it easy to understand. Further, the design artifacts are presented with sufficient details to enable technology-oriented audience (i.e. practitioners) to implement the design principles identified. In this regard, for instance, each design principle is supplemented with practical examples as well as examples from users feedback to help audience understand well the design principles. These details provide managers with the knowledge required to effectively apply the design principles within specific context (i.e. diabetes) as well as enable researchers to build a cumulative knowledge base for further extension and evaluation.

CHAPTER 4

TEXT-MINING BASED APPROACH

This chapter discusses the technique adopted in this project for discovering design features from online users reviews of the diabetes applications. First, it describes the data collection and preparation. It then explains the topic modeling technique used to extract design features from online users reviews. Finally, the chapter discusses the process for developing the design principles and concludes with presenting the topics extracted along with their assigned labels. Figure 4.1 shows the architecture of the text mining-based approach adopted in this study.

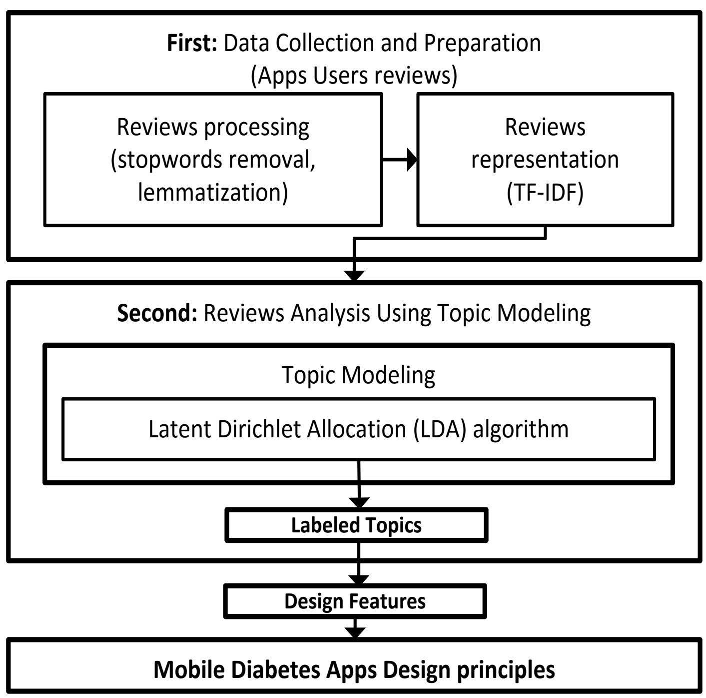

Figure 4.1. Overview of the proposed text mining based approach

4.1 Data Collection and Preparation

The data for this study was collected from Apple iTunes store[1]. First, the keyword "diabetes" was used to retrieve all diabetes related applications. Second, we filtered the applications. To be included in the study, an application must provide functions to support diabetes self-management. We excluded applications without English-language user interfaces as well as those intended exclusively for health care professionals. As a result, 30 applications were selected. For each iOS application, the reviews posted by the users were gathered using the Apple store API. Through this process, we obtain our data set consisting of 4,218 reviews (140.6 reviews per app on average). Table 4.1 summarizes the collected data.

Table 4.1. Summary of apps data

Count of apps	Count of user reviews	Mean	Std Dev	Median	Min	Max
30	4,218	140.6	116	100	50	450

For the names of the applications, see Appendix A. When preprocessing the data, we removed stop words, performed lemmatization, which means converting words in inflected forms (e.g., plural nouns and past-tense verbs) to their original forms, and represented each document using the well-known Term Frequency Inverse Document Frequency (TF-IDF) weighting scheme (Haddi et al. 2013). Specifically, TF-IDF weight of a word *i* in a document *j* is given by

$$F_{i,j} * Log\ (N/DF)$$

Where $F_{i,j}$ is the frequency of the word *i* in the document *j*, N indicates the number of documents in the corpus, and DF is the number of documents that contains word *i*.

[1] The date of collecting data is January 11, 2015.

4.2 Topic Modeling: LDA

Topic models are statistical-based algorithms for discovering the main themes (i.e. set of topics) that describe a large and unstructured collection of documents. Topic models allow us to summarize textual data at a scale that is impossible to be tackled by human annotation. Topic modeling algorithms do not require any prior labeling or annotations of the documents and allow the topics to emerge from the analysis of the original texts (Blei 2012). We select the LDA (Latent Dirichlet Allocation) model, the most common topic model currently in use, due to its conceptual advantage over other latent topic models (Blei et al. 2003). The model generates automatic summaries of topics in terms of a discrete probability distribution over words for each topic, and further infers per-document discrete distributions over topics. The interaction between the observed documents and hidden topic structure is manifested in the probabilistic generative process associated with LDA. This generative process can be thought of as a random process that is assumed to have produced the observed document (Bao and Datta 2014). To illustrate the results of LDA, Let $M, K, N,$ *and* V be the number of documents in a collection, the number of topics, the number of words in a document, *and* the vocabulary size, respectively. The first result is the $M \times K$ matrix, where the weight $w_{m,k}$ is the association between a document d_m and a topic t_k. In our case, the documents are user reviews for diabetes apps (i.e. we integrated the reviews of all apps in a big data file and treat each user review as one document) (M=4,218). The second result is the $N \times K$ matrix, where the weight $w_{n,k}$ is the association between a word w_n and a topic t_k. The notations *Dirichlet*($\cdot$) and *Multinomial*($\cdot$) represent Dirichlet and multinomial distribution with parameter ($\cdot$), respectively. The graphical representation of LDA is shown in Figure 4.2, and the corresponding generative process is shown below:

(1) For each topic $t \in \{1, ..., K\}$,

(a) draw a distribution over vocabulary words

$\boldsymbol{\beta}_t \sim Dirichlet(\boldsymbol{\eta})$.

(2) For each document d,

(a) draw a vector of topic proportions

$\boldsymbol{\theta}_d \sim Dirichlet(\boldsymbol{\alpha})$.

(b) For each word w_n in document d, where $n \in \{1, ..., N\}$,

(i) draw a topic assignment

$\mathbf{z}_n \sim Multinomial(\boldsymbol{\theta}_d)$;

(ii) draw a word $w_n \sim Multinomial(\boldsymbol{\beta}_{\mathbf{z}_n})$.

The notation $\boldsymbol{\beta}_t$ is the *V*-dimensional word distribution for topic *t*, and $\boldsymbol{\theta}_d$ is the K-dimensional topic proportion for document *d*. The notations $\boldsymbol{\eta}$ and $\boldsymbol{\alpha}$ represent the hyperparameters of the corresponding Dirichlet distributions.

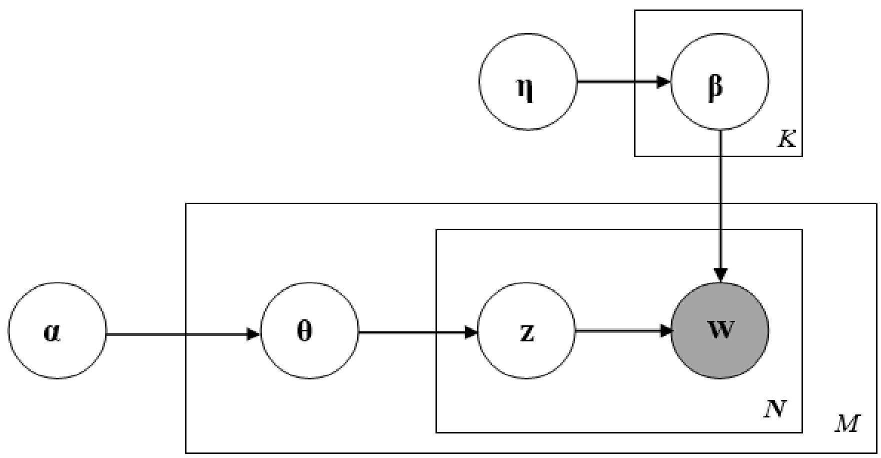

Figure 4.2. Graphical Model of LDA

4.2.1 Predictive Power of Topic Models

The most typical evaluation of topic models includes measuring how well a model performs when predicting unobserved documents. Specifically, when estimating the probability of unseen held-out document given a set of training documents, a "good" model should give rise to a higher probability of held-out documents. Therefore, to measure the predictive power of LDA models with different number of topics, we use a metric called perplexity that is conventional in language modeling (Azzopardi et al. 2003). The perplexity can be understood as the predicted number of equally likely words for a word position on average, and is a monotonically decreasing function of the log-likelihood. Thus, a lower perplexity over a held-out document is equivalent to a higher log-likelihood, which indicates better predictive performance (i.e. lower perplexity score indicates better generalization performance) (Blei et al. 2003). Formally, for a test set D_{test} of M documents, the per-word perplexity is defined as

$$Perplexity(D_{\text{test}}) = \exp\left(-\sum_{d=1}^{M} \log p(w_d) / \sum_{d=1}^{M} N_d\right),$$

Where N_{d} is the number of words in document d (Blei et al. 2003).

In our experiment, we trained a number of LDA models with different number of topics (k) and evaluated them against a held-out test set. In particular, we computed the perplexity of a held-out test set to evaluate the models. We held out 20% of the data for test purposes and trained the models on the remaining 80%. Figure 4.3 shows the predictive power of the models in terms of the held-out per-word perplexity by varying the number of topics. The figure shows that the perplexity decreases with the increase of the number of topics, but tends to converge to a fixed value eventually. This occurs at around 50 topics, hence we set the number of topics to 50 .

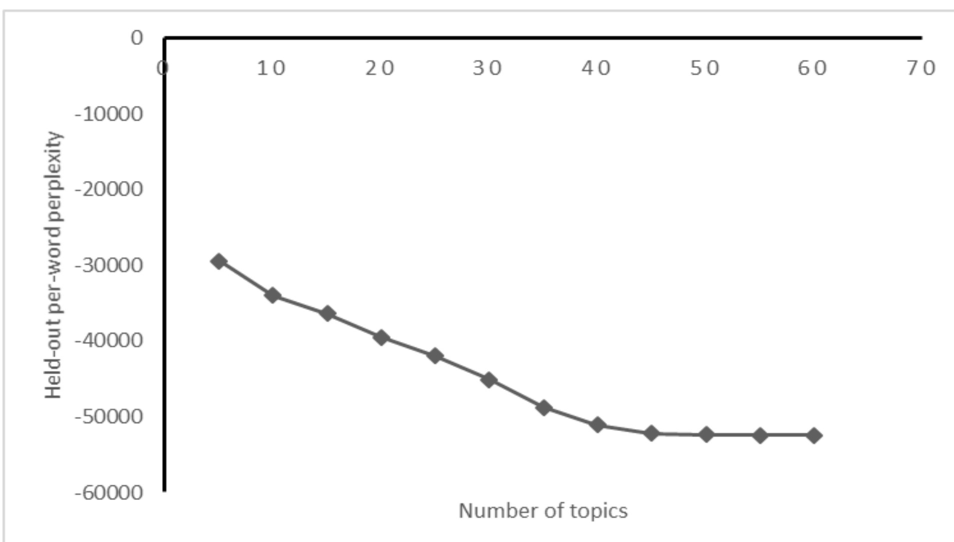

Figure 4.3. Held-out per-word perplexity

4.2.2 Topics Labeling

Before using the topics learned by topic models to develop design principles, the topics need to be labeled so that we could determine what each topic pertains to. In the literature, topics are usually manually labeled to ensure high labeling quality (Chang et al. 2009) especially when such labeling requires domain knowledge (mobile health applications knowledge in our case). We thus manually labeled the topics learned based on the top 10 words in each. There are a number of user reviews that does not reference a specific design feature but pertain to other aspects of the apps (e.g., "*The app is pricey*", "*this app is well worth the price for me*", etc. "). We hence ignored the topics that reflected aspects (e.g., price) irrelevant to the design of the apps. Overall, we were able to assign labels to 32 topics that are related to the design of the apps. Table 4.2 presents the 32 topics learned by our LDA model. Each topic is visualized using word clouds, where the font size corresponds to the probability of the word occurring in the topic. To ensure that our labeling was not biased, we asked a doctoral student who have a domain knowledge in mobile diabetes self-care area (i.e. human expert) to independently label the 32 topics obtained. Before the student started tagging, we provided him with the 32 topics labels, which were used as the fixed set of candidate labels. A kappa statistic was computed between the student's labeling results and ours, with a value of 0.7239. According to exiting literature (Landis and Koch 1977), the kappa score indicates substantial agreement between the two sets of tagging results. Therefore, we did not pursue resolving disagreement between our tagging results and those of the human expert.

Table 4.2. Topic labeling. Topic1 to topic 32 are displayed from left to right, top to bottom

data sync ipad doc iphone help visual written immediately	**cloud device graphic sync app transfer potential suppose worth money**	**Server app upload data ipad support able visit ago work**	**free server app sync data use lack look develop like**
T1: Sync between ipad and iphone	*T2: Sync with cloud*	*T3: Sync with server*	*T4: Sync with server*
convenient meter connect glucose phone app cable book picture fail	**pump believe insulin medtronic dose purchase basal ingredients asset minimum**	**doctor great data email love app use diabetes easy highly**	**excel place export**

			endocrinologist data usage respond confuse app product
T5: glucose meter	*T6: insulin pump*	*T7: Communicate data with doctors*	*T8: Communicate data with doctors*
pdf export excel file like data glucometer constant dump harder	support forum group help people site recent progress condition great	track sugar blood carb help glucose use diabetes app control	great allow monitor blood glucose progress level ask share need
T9: Export data	*T10: Support forum*	*T11:Track blood sugar and carb*	*T12: Track blood glucose and progress*
dosage pilot medicine track mmol saver exist obvious bed palm	handy lot information track help sugar program come iphon app	job amazing weekly maintain guy monthly blank health blog register	app food data use log read track great need diabetes
T13: Track medications	*T14: Track lot of information*	*T15: Tracking*	*T16: Track foods*
good app track carb work appreciate bolus like neat feel	calculate figure let appear level everything rock occur software copy	help motivate track plus keep really sure app step daily	graph read nice usable report trend comment icon short tire
T17: Track carb	*T18: Calculation*	*T19: Tracking*	*T20: Graphs and report*
glance extremely graph trend see thing form flaw easier bg	table bit kept spreadsheet display list value gain edit process	awesome option allow customize need app thank self output mean	remind watch like feature team lite setup real room app
T21: Graphs	*T22: Graphs and reports*	*T23: Customization*	*T24: Reminders*
ease use great app super comprehensive help beat doctor everything	friendli user monster organ use worth lot app affect little	fun complicated journal ease use straight correctly definitely password app	work great daughter simple challenge basic app need quantity number
T25: Easy to use	*T26: User friendly*	*T27: Easy to use*	*T28: Simple app*

button navigation shut click aid standard close protein remove method	**delete data intuitive twice couple bad mg lost decent non**	**like scanner barcode stuff adapt age care jot situation minim**	**bar code scan reader tech like data enjoy recognize dietary**
T29: Navigation	*T30: Data editing*	*T31: Barcode scanner*	*T32: Barcode scanner*

CHAPTER 5

RESULTS AND DISCUSSION

This chapter discusses the design principles discovered. First, it presents the design principles distributed into four categories along with definitions, practical examples as well as instances from users' feedback. Second, the design principles for top rated user-ratings (i.e., 4 and 5 star) are compared against those for low rated user ratings (i.e., 1 and 2 star). Finally, the chapter compares the design principles with existing literature.

5.1 The Design Principles Discovered

The 32 topics obtained from the topic modeling were first mapped to 15 design features, the leaf nodes in Figure 5.1. The mappings between the topics and the design features are often one-to-one. For example, the topics "Sync between iPad and iPhone" was mapped to the design feature "Sync between devices", the topic "Glucose meter" to the feature "Integration with glucose meter", and "insulin pump" to "Integration with insulin pump". Some features correspond to multiple topics. For instance, T20 "Graphs and reports", T21 "Graphs" and T22 "Graphs and reports" shown in Table 4.2 were mapped to the design feature "Graphs and reports". The design features obtained were then mapped into 11 design principles distributed into four sets as shown in Figure 5.1. For example, "Sync between devices" and "Sync with cloud" design features were mapped to the "Integration with Information Systems (IS)" design principle, "Integration with glucose meter" and "Integration with insulin pump" were mapped to "Integration with medical devices", and "Communicating data with doctors" and "Export data" were mapped to "Communication with doctors".

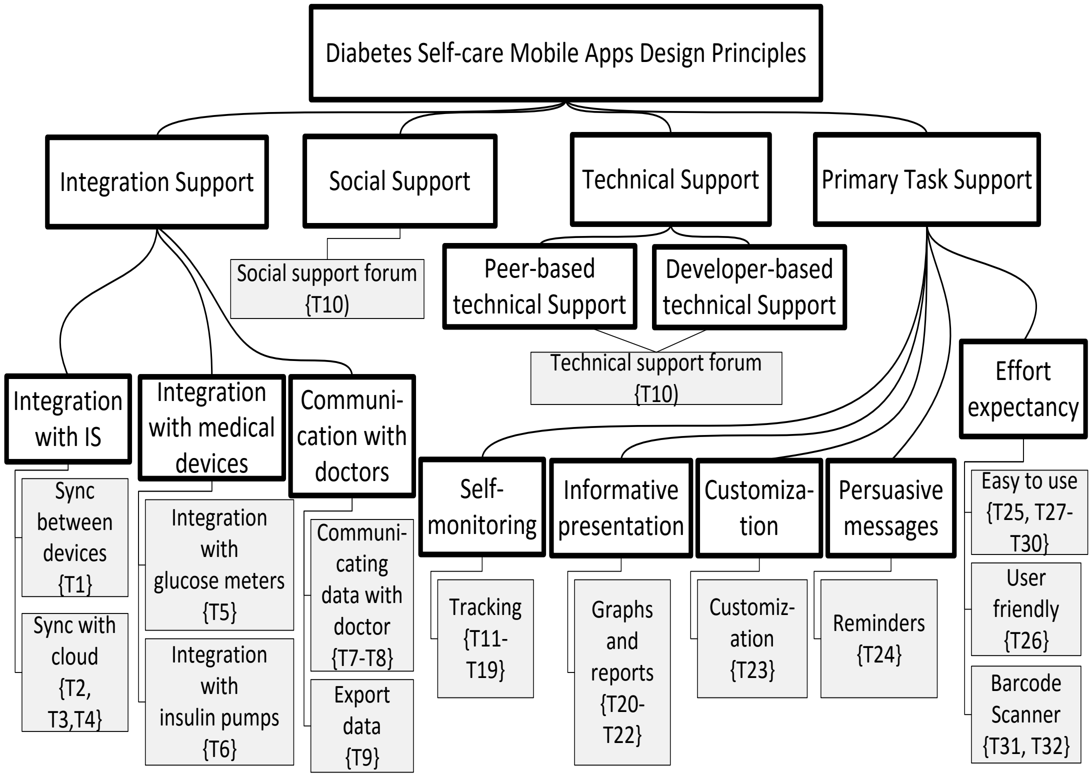

Figure 5.1. The structure of the design principles discovered

Table 5.1 shows the three design principles related to the integration of the apps with other supporting elements in users' context. First, the principle "Integration with Information Systems (IS)" reflects those topics pertaining to synchronization of data between mobile devices and the cloud {T1-T4}. Second, {T5 and T6} represent the design features "Integration with glucose meters" and "Integration with insulin pumps", which were subsequently mapped to "Integration with medical devices". Finally, {T7-T9} related to exporting health-related data into suitable files such as pdf and emailing doctors the data were generalized into the design principle "Communication with doctors".

Table 5.1. Integration support design principles

Design Principle	Practical Examples	Examples from users feedback
Integration with medical devices	Enable users to synchronize their pump data (i.e. Basel	- I need it to sync to my meters and pump.

Diabetes self-management systems should help users to connect with the medical devices in their health environment such as glucose meter and insulin pump.	and Bolus ratios) with the app.	- Needs ability to enter pump basal rates. - No support for insulin pumps and basal rates.
Communication with doctors Diabetes self-management systems should help users to communicate their historical data with doctors.	Enable users to export and communicate their health-related data with their doctors.	- But unless can back up and send reports to my doctor it has become worthless.
Integration with Information Systems (IS) Diabetes self-management systems should help users to synchronize their data with other systems such as mobile devices, Web server and cloud.	Support real-time synchronization of patients' data with a web server. Support synchronization between mobile devices (i.e. iPhone and iPad)	- Would be even better if it had the ability to sync across devices. - I can't set it up to synch between my iPad and iPhone apps. - Cannot use iCloud to store data and communicate between devices

To further understand the contextual meaning of "support forum" topic {T10}, we investigated the reviews that are highly associated with this topic. We found that users mentioned two types of support forums, technical and social. Hence, we mapped this topic to two design features, "Social support forum" and "Technical support forum", which were then mapped to two design principles "Social support" and "Technical support" as shown in Table 5.2 and Table 5.3 respectively. "Social support" indicates that health BCSSs should support building peer-to-peer user communities that enable users to find those with similar health concerns to share experience and support. Such support perceived from community members is expected to persuade users to change their health behavior. To this end, it is useful for healthcare mobile apps to build functions such as a social forum, where users can meet and socially support each other.

Table 5.2. Social support design principle

Design Principle	Practical Examples	Examples from users feedback
Social support Diabetes self-management systems should help users to connect with their peers to share support and motivation to achieve their goals better.	Provide a social forum, which help all app users to meet together and share experience and emotion. Support integration with social media.	- Very supportive community and educational. - It's nice to have people to talk to that understand exactly what you're going through. - The people on here are so encouraging.

"Technical support", on the other hand, refers to providing users with adequate technical support when they have problems using the system (Singh et al. 2010). Such support can come either from other users (i.e. peer support) via providing technical support forum or from the system developers (i.e. developers support) who can respond to users' questions.

Table 5.3. Technical support design principles

Design Principle	Practical Examples	Examples from users feedback
Peer-based technical support The Diabetes self-management systems should provide users with peer-based technical support where users	Provide a user support forum to help app users solve technical problems.	- The user support forum also has not been working for at least a week.

can get help from other users when they have problems using the system.		
Developer technical support The developers of Diabetes self-management systems should ensure that there is responsive and sufficient technical support available to the users when they have problems using the system. (Singh et al. 2010)	Provide a responsive customer support that promptly answer users inquiries.	- Sent two emails with questions, no response and yes it has been over a week. - Support is non-responsive. - It appears that app support is non-existent - With NO SUPPORT this app is JUNK. - Very Poor customer support. I do not recommend this app.

Table 5.4 shows the five "primary task support" design principles we developed based on users' reviews. These principles support the primary tasks of diabetes self-management, including "Self-monitoring", "Informative presentation", "Effort expectancy", "Persuasive messages" and "customization", each of which corresponds to one or more topics we obtained from LDA. First, {T11-T19} (see Table 4.2 above) are related to tracking all diabetes-related aspects including blood glucose, carb, medication, progress, and doing calculations and were hence mapped to the "Self-monitoring" design principle, which calls for providing means for users to track their performance or status for all their health related aspects (Oinas-Kukkonen and Harjumaa 2009). Second, {T20-T22} are related to graphs and reports that display data in different formats and were thus mapped to the "Informative presentation" principle, which refers to presenting users' data in a way that is readable as well as depicting users' improvements trends and historical patterns (El-Gayar et al. 2013c). Third, T23 was mapped to "Customization", which calls for providing users with customizable options that adapt to the potential needs, interests, personality, usage context, or other factors (e.g., type 1 vs type 2

diabetic) relevant to a user. Fourth, T24 was mapped into the principle “Persuasive messages”, which refers to the app’s effectiveness in reminding users of their target behavior (Oinas-Kukkonen and Harjumaa 2009). Finally, {T25-T32} are related to ease of use, user-friendly interface, easy navigation and data editing as well as using a barcode scanner to reduce data input efforts. Thus, these topics were mapped to the “Effort expectancy” design principle, which refers to the degree of ease associated with the use of the app (Venkatesh et al. 2003).

Table 5.4. Primary task support design principles

Design Principle	**Practical Examples**	**Examples from users feedback**
Self-Monitoring Diabetes self-management systems should provide means for users to track their all health-related aspects. (Oinas-Kukkonen and Harjumaa 2009)	Track blood sugar, diet, exercise, meals, food, carbs, and medications.	- The app makes keeping track of glucose levels, carb intake, and medicine I took. - Keep track of my BG and insulin intake. - The app keep track of diabetes related things.
Informative Presentation Diabetes self-management systems should be able to provide users with readable and informative graphs, reports, and charts of their health-related	Provide a single chart combined all user’s information such as blood glucose, carbs, and exercise, so he can see trend Provide clear displayed graphs and reports upon request.	- The report feature is handy for seeing trends. - I especially like the graphs, where I can see trends and averages over time. - I like the different charts available it makes it easy to see your personal trends. - The color coding along with

data depicting their improvement patterns and historical trends. (El-Gayar et al. 2013c)		the charts really helped me identify certain patterns that I never knew were happening.
Effort Expectancy Diabetes self-management systems should reduce effort that users expend with regard to use, entering their health-related readings and data and update the existing ones. (Venkatesh et al. 2003)	Entering diabetes-related data such as blood glucose level, pressure, medications, and weight should be easy task. Provide a bar code scanner to make entering new food item is easy task.	- Great barcode database and easy to enter foods. - I love the barcode scanner to enter the food. -The app is very easy to use and new data can be entered quickly. - I really like the ease of entering in my readings.
Persuasive messages Diabetes self-management systems should remind users of their target behavior during the use of the app. (Oinas-Kukkonen and Harjumaa 2009)	Having a remind feature for glucose, medications and meals.	- The constant visual reminder really helps keep you on track. - This app is truly helping me, it sends me reminders and is very easy to use. - The reminders keep me on track when I'm busy or just forgetful.
Customization Diabetes self-management systems should provide users	Enable users to change measurement units (i.e. kg/pounds, meters/inches), and select a glucose threshold to be	- Personalized options such as being able to choose a glucose threshold that the app would use to flag a reading, push

with customizable options to the potential needs, interests, personality, usage context, or other factors relevant to a user (i.e. type 1 and type 2 diabetic).	used to generate notifications. Having voice interaction to support blind users.	notifications, location services, etc. - I am on 2 insulins and take them often at the same time. It doesn't allow for 2 insulins -Cholesterol units are mg/dl and I can't change them.

5.2 Design Principles in High Rating Reviews vs. those in Low Rating Reviews

To further investigate the importance of each design principle, we performed separate topic modeling to identify design principles for top-rated user reviews (i.e., 4- and 5-star reviews) and for low-rated user reviews (i.e., 1- and 2-star reviews). Table 5.5 shows the design principles discovered in each group and their significance.

As shown in Table 5.5 below, the two sets of reviews intersect in four design principles including "Effort expectancy", "Self-monitoring", "Informative presentation", and "Communication with doctors". Hence, the missing or ineffectiveness of these design principles may lead to dissatisfaction (complaining or suggestion behavior) as shown in a 1-star review "*as to entering food for carb control it is tedious*" (complaining) and a 4-star review "It *would be nice if there was an option to scan the bar code of products instead of having to manually enter info if you can't find it in the food list* (suggestion). At the same time, the presence of these design principles has led to satisfaction and complimenting behavior in top rated reviews as shown in a 5-star review *"I love the barcode scanner to enter the food"*. Since the missing or ineffectiveness of these design principles has led to dissatisfaction behavior in low rated users review, and their presence and effectiveness have led to satisfaction behavior in top rated review, we labeled them as the "essential" principles in Table 5.5.

Table 5.5. Design principles in high rating reviews vs. those in low rating reviews

Design principle	**High rating reviews**	**Low rating reviews**	**Significance**
Effort expectancy	✓	✓	*Essential*
Self-monitoring	✓	✓	*Essential*
Informative presentation	✓	✓	*Essential*
Communication with doctors	✓	✓	*Essential*
Integration with Information Systems (IS)		✓	*Indispensable*
Integration with medical devices		✓	*Indispensable*
Customization		✓	*Indispensable*
technical support		✓	*Indispensable*
Social support	✓		*Enhancing*
Persuasive messages	✓		*Enhancing*

The two sets of reviews are however disjoint in the remaining design principles. While users in top rated reviews did not report design features related to "Integration with Information Systems (IS)", "Integration with medical devices", "Customization", and "Technical support" design principles, the absence of any of these design principles has led to dissatisfaction behavior (complaining or suggestion behavior) in the corresponding low rated reviews. Thus, we labeled these design principles as "indispensable" in Table 5.5.

Design principles such as "Social support" and "Persuasive messages" were mentioned in top-rated reviews but not in low-rated reviews. Whereas the absence of these design principles might not have been noticed and did not lead to complaints in low rated reviews, their presence or absence has led to compliments or suggestions in high-rated reviews as shown in the following examples "*Being a diabetic and having a platform to quickly connect and share with others who have this rotten disease makes the struggle to regain your health easier*", and *“A reminder feature would be a nice enhancement”*. The absence of these design principles did not directly result in complaints in low-rated user reviews, but their presence seems to enhance user satisfaction as shown in top-rated reviews. We hence labeled them as “enhancing” in Table 5.5.

5.3 Comparison with Pertinent Literature

In this section, we compare the design principles discovered with existing related literature. Table 5.6 below summarizes the comparison results of our data-grounded design principles extracted from the actual use of diabetes mobile applications with the design principles developed by Oinas-Kukkonen and Harjumaa (2009), the literature of health BCSSs acceptance factors and Technology acceptance for elderly patients/Telehealth systems.

Table 5.6. Comparison with existing literature

	Primary task support					**Integration support**			**Social**	**Technical**
Study	**Self-Monitoring**	**Informative Presentation**	**Effort Expectancy**	**Persuasive messages**	**Customization**	**Integration with IS**	**Integration with medical devices**	**Communication with doctors**	**Social support**	**Technical support**
Design principles developed by Oinas-Kukkonen and Harjumaa										
Oinas-Kukkonen and Harjumaa (2009)	*		*	*	*				*	
Literature of Consumer health information technology (CHIT) acceptance										
Or et al. (2011)			*							

Lehto et al. (2012)	*		*			
Ruland et al. (2013)					*	
Karppinen et al. (2014)		*				* Technological issues
Technology acceptance for elderly patients/Telehealth systems						
Singh et al. (2010)		*	*		*	*
Cimperman et al. (2013)		*			*	*
Peek et al. (2014)					*	
Electronic Patient Record (EPR) literature						
Berg et al. (1998)				* (structure)		

First, with regard to the comparison with the persuasive systems design principles developed by Oinas-Kukkonen and Harjumaa (2009), our findings present empirical support of overall five of their design principles. Regarding their primary task support category, we provide evidence of three principles in this category, 1) *reduction* which corresponds *Effort expectancy* in our study, 2) *self-monitoring* and 3) *tailoring* that corresponds our *customization principle*. In their dialogue support category, we find evidence of 4) *reminders* design principle that corresponds *persuasive messages*. Finally, 5) our *social support* principle supports their social support design principles. According to (Oinas-Kukkonen and Harjumaa 2009), great care should be given to support the social aspects of persuasive systems, including *social learning from peers, social comparison with peers, normative influence (i.e. peer pressure), social facilitation, cooperation, competition and recognition.* Grounding these principles in users' feedback helps provide empirical basis and further demonstrates the importance of these design principles for self-care mobile systems. Also, we note that "*Informative Presentation*", "*Integration Support (Integration with IS, Integration with medical devices,* and *Communication with doctors)*" and "*technical support*" design principles are missing in (Oinas-Kukkonen and Harjumaa 2009). *The informative presentation* design principle is expected to improve the persuasiveness of health BCSSs through nudging users toward healthy behavior. Actually, depicting users' improvement patterns and historical trends using graphs and reports will motivate users toward better behavior change. Therefore, the study adds *the informative presentation* to the existing persuasive design principles developed by (Oinas-Kukkonen and Harjumaa 2009).

Second, in regard to the comparison with the literature of health BCSSs acceptance factors and technology acceptance for telehealth systems, the results revealed that *the informative presentation*, *customization* and *Integration Support (Integration with IS, Integration with medical devices,* and *Communication with doctors)* design principles are missing in these studies. However, for *the technical support*, we find evidence in literature of Consumer health information technology (CHIT) acceptance that technical issues are important for BCSS acceptance. Further, we find technical support evidence in technology acceptance for elderly patients/Telehealth systems. Moreover, in literature regarding Electronic Patient Record (EPR), Berg et al. (1998) demonstrated the importance of incorporating structure in the ERP, which is related to our *integration support* design principles. Therefore, this work introduces *informative presentation, customization*, *integration Support and technical support* as important factors for BCSSs acceptance.

CHAPTER 6

DEMONSTRATION AND EVALUATION

To evaluate the significance of the design principles we identified, we investigated the relationship between the design principles and user ratings. We first examined the relationship between the design principles and users' complaints (i.e., 1- or 2-star reviews). We then performed another empirical study to prove the relationship between the number of design principles incorporated in apps and user ratings.

6.1 Relationship to Users' Complaints

We focused on users' complaints contained in 1- or 2-star reviews since in comparison with high-rated reviews, these low-rated reviews are more likely to reflect the user concerns and shed lights on design principles that should be considered but unfortunately ignored in the current research and practice.

6.1.1 Frequency of the Design Principles

We first considered the frequency of occurrences of each principle in the complaints. Showing that one design principle has been frequently mentioned in the complaints provides evidence of the importance of that design principle. As discussed in section 5.1 "The Design principles discovered", we mapped the topics extracted using LDA to a set of design principles, each of which is pertinent to one or more design features. Hence, instead of directly counting the frequency of the design principles, we first mapped the complaints contained in 1- and 2-star reviews to the design features. We noticed that in one review, users could complain about multiple features; hence, we split such a review into multiple complaints, each of which pertains to just one feature. We also ignored the reviews irrelevant to the design of the apps and labeled the complaints (e.g., "*Not that good. Used much better ones*") that are generic and cannot be mapped to a specific design feature as "others". In total, we tagged 500 complaints out of 526 1- and 2star reviews. To ensure that our tagging was not biased, we provided a graduate student with the set of design features we identified previously and asked the student to independently tag a statistically representative sample of the complaints. This sample of reviews is randomly chosen to achieve a 95% confidence level and a 5% confidence interval. This means that we are 95% confident that each of the results is within a margin of error of ±5%. The statistically representative sample for 500 reviews, with a 95% confidence level and a 5% confidence interval, is 217 reviews[2]. The kappa statistic was computed between ours and the students' tagging results with a value of 0.7559, which indicates substantial agreement between the two sets of tagging results (Landis and Koch 1977). After finishing tagging the reviews, we counted the frequency of each design feature in the complaints, and then by summing up the frequency of the design features belonging to each design principle, we obtained the frequency of each design principle mentioned in the complaints. The "most frequent" column of Table 6.1 shows the rank and the frequency in percentage of each design principle and its associated design features.

Table 6.1. The most frequent and impactful design principles in users' complaints

Design principle	Most Frequent		Most Impactful	
	Rank	**Percentage(%)**	**Rank**	**1:2 star***
Effort expectancy	**1**	**18.2**	**3**	**1.7**
Easy to use		15.0		2.7
User friendly		2.2		0.6
Barcode scanner		1		0.7
Integration with Information Systems (IS)	**2**	**16.2**	**2**	**2.0**
Sync with cloud		12.0		2.5
Sync between devices		4.2		1.1
Self-monitoring	**3**	**10.0**	**8**	**0.7**

[2] Creative Research Systems, http://www.surveysystem.com/sscalc.htm Accessed on February 2016.

Tracking		10.0		0.7
Informative presentation	**4**	**9.2**	**6**	**1.2**
Graphs and reports		9.2		1.2
Technical support	**5**	**8.4**	**1**	**3.7**
Technical support forum		8.4		3.7
Personalization	**6**	**7.8**	**4**	**1.6**
Customization		7.8		1.6
Communication with doctors	**7**	**6.6**	**5**	**1.5**
Export data		3.8		1.4
Communicating data with doctors		2.8		1.8
Integration with medical devices	**8**	**4.8**	**2**	**2.0**
Integration with glucose meter		4.2		2
Integration with Insulin pump		0.6		2
Persuasive messages	**9**	**0.4**	**7**	**1**
Reminders		0.4		1
Social support	**10**	**-**	**9**	**-**
Total		**81.6**		

*: The ratio of 1 to 2-star ratings for each design principle. For example, a 1 to 2-star ratio of 2 for a design principle indicates that this design principle has 2 times as many 1-star ratings as 2-star ratings.

Overall, we find that the design principles identified represent 81% of the negative reviews. We can see that the "*Effort expectancy*" complaints in 18.2% of the reviews, "*Integration with Information systems (IS)*" in 16.2%, "*Self-monitoring*" *in 10%,*"*Informative presentation*" in 9.2%, "*Technical support*" in 8.4%, "*Customization*" in 7.8%, "*Communication with doctors*" in 6.6% and "*Integration with medical devices*" in 4.8%. Together, these eight design principles account for more than 80% of all complaints.

These results first emphasize the importance of effort expectancy, the most frequent design principle in users' complaints. According to the principle, diabetes mobile apps should be designed in a way that reduce effort that users spend with regard to use of the system. For example, a barcode scanner could significantly reduce data input overhead.

The results shown in Table 6.1 also highlight the importance of the three design principles related to integration (including “Integration with IS”, “Communication with doctors” and “Integration with medical devices”), which account for more than 25% (15.4+6.6+4.8) of all the complaints. These integration-related design principles are critical for mobile apps but have been largely ignored in the extant literature. Among the three principles, special attention should be paid to “Integration with Information systems (IS)”, which ranked the second in frequency among all the principles. In fact, we find numerous user statements of negative user experiences regarding this design principle such as the following examples. “*The server does not work anymore so you can’t sync your entries*” and “*The app does not synch data between iPhone and iPad version of the app*”. Besides, attention should also be given to “communication with doctors” design principle as in these complaints *“it would not let me create a .pdf to send to my doctor”* and *“but unless can back up and send reports to my doctor it has become worthless”*. The last integration type that should also be considered is “the integration with medical devices” as shown in the following users’ complaints *“I need it to sync to my meters and pump” and “I need it to sync to pump”*.

Our findings also indicate the importance of “self-monitoring” *(i.e. the third most frequent principle)*, which means that mobile diabetes apps should provide functions that enable users to track a comprehensive list of health-related aspects. In the reviews, there were frequent user statements of unsatisfying user experiences with self-monitoring like the following examples. “*Wasn’t able to accurately track my medication”, “I can’t log any activities!”, “Can enter my A1C, but can’t track it”, “I am a type 2 diabetic, use a slow and fast acting insulin as well as two different oral meds. This app does not have a way to track this”, “Nothing about exercise, which I think is important”, and “so you can’t write how many carbs you ate before giving an injection or bolus”*

We also found that “Informative presentation” is frequently mentioned in the complaints, which demonstrates that it is important to use graphs and reports to depict users’ improvement patterns and trends. Below are two examples where a user reported a problem related to this design principle.

“*does not provide any way of combining the information so that you can see trends”* *"can't be used to produce a high-low-average sugar chart to help me see trends and adjust my medications"*

The fifth most frequent complaint type, "technical support", demonstrates the importance of this design principle in health BCSSs. Actually, we found two types of technical support where users complained about. First, peer-based technical support represented in a support forum where users can get help from other users. Second, developer support where users can e-mail developers (i.e. support staff) when they have a technical problem during using the system. Below are two examples from users complaints

"No response for a week from support email address. The user support forum; also has not been working for at least a week"

"Sent two emails with questions, no response and yes it has been over a week"

The results also highlight *customization* as a frequent complaint type. Some users reported that the system is not customizable as in the following complaints "*Hardly any customization allowed*" and "*It is much less customizable than the reviews imply*". What we find interesting was that most of the complaints related to customization refer to the imbalance between some systems features and the actual context of using the system. For example, the foods offered by the system don't reflect users characteristics as in the following two complaints "*has features like ;foods; that don't reflect my eating choices at all*" and "*I can't use the food portion as I don't eat processed food*". These examples illustrates the importance of having customizable food list that can reflect the different users' eating habits and preferences. Also, the measurement units and the types of exercises that the system can track should be customizable to reflect users' actual context and characteristics. This is reported in the following two complaints "*Haven't been able to find a way to use mmol/L as an input, the standard here in Europe*" and "*Only 1exercise category...walking. Some of us also run bike and swim*".

On the other side, we found that the principles that have been least frequently mentioned in user complaints include "Persuasive messages" and "Social support". In particular, "Social support" has not been mentioned in any of the complaints. A further investigation of the 30 diabetes apps revealed that one of them, Diabetic Connect[3], mentioned a "social forum" in its product description. While users did not complain of the lack of social support in other applications, the existence of the social forum in Diabetic Connect has brought about users' praises. For instance, in a 5-star review, a user applauded the social forum: "*Being a diabetic and having a platform to quickly connect and share with others who have this rotten disease makes the struggle to regain your health easier*". Our findings are consistent with the existing research such as Chomutare et al. (2011) that pointed out that social network functions such as social forums are largely missing in current mobile health apps. In order to enhance the design of health apps, it is critical for practitioners to take a holistic socio-technical approach and focus on not only the technical issues but also the social aspects of the apps.

6.1.2 Impact of Each Design Principle

Next, we ranked the design principles with respect to their impact on users' negative ratings (see the "most impactful" column in Table 6.1). Analyzing the impact of the design principles on the user ratings adds another dimension for analyzing the importance of the different design principles. While a design principle *A* may be more frequently mentioned in the complaints than another principle *B*, users may be less concerned about *A* and give higher ratings (in this context, 2-star ratings rather than 1-star ratings). Principle *B*, on the other hand, may appear less frequent than *A* in the complaints, but the lack of the principle could be more negatively perceived and lead to 1-star ratings.

To compute the impact of each design principle, we adopt the approach followed by Khalid et al. (2014). We determine the most negatively-perceived design principles by looking at the ratio of 1 to 2-star ratings for each design principle. For example, a 1 to 2-star ratio of 2 for a design principle indicates that this design principle has 2 times as many 1-star ratings as 2-star ratings. Columns 4 and 5 of Table 6.1 show the rank and the 1:2 star ratio for each design principle and its associated design features. It turned out that the most negatively-perceived design principles were different from the most frequent principles. Observing the

[3] https://itunes.apple.com/us/app/diabetic-connect/id418076239?mt=8

results in Table 6.1, we noticed that problems related to the principle “Technical support” were the most negatively perceived by users. Also, we noticed that the frequency and impact of this principle diverged in terms of the rank. While “Technical support” was only fifth in frequency, it ranked the first in impact. This demonstrates that the principle “Technical support”, which has been largely missed in the existing research, has a significant impact on user ratings, though it is less frequently mentioned in the complaints than some other principles.

This impact of technical support on user satisfaction could also be explained by the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). According to this theory, *the degree to which an individual believes that an organizational support exists to support the use of the system* is significant to motivate individuals to use the technology. Higher levels of technical support are believed to promote more favorable beliefs about the technology, which could then improve acceptance (Igbaria et al. 1995).

“Integration with Information systems (IS)” and “Integration with medical devices” were tied for the second rank in impact. Again, these two design principles have been largely ignored in the existing research. In particular, “Integration with IS” achieved high ranks in both impact and frequency. This indicates that in the era of the Internet of Things, supporting mobile health apps with cloud computing and integrating them with medical devices (such as insulin pumps in the context of diabetes apps) have become an essential requirement for the design of mobile health apps.

Integrating users with the supporting elements in their health environment such as glucose meter, insulin pump, clouds, other mobile devices and doctors could be considered as facilitating condition. Based on the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003), the facilitating conditions, *the degree to which an individual believes that a technical infrastructure exists to support use of the system*, are significant to motivate individuals to use the information technology.

"Effort expectancy" ranked the third in impact. Particularly, many users were frustrated when the apps entailed significant efforts at data entry and when it was difficult to update the readings in some of the apps. It was followed by "Customization", "Informative presentation", and "Persuasive messages" in the ranking of impact. This suggests that building customizable system that fit users actual context, providing users with informative graphs and reports describing their performance, and notifying them regarding their target behavior are also important. Finally, our findings show that users were least concerned about the issues related to the "Self-monitoring".

6.2 Relationship Between Number of Design Principles and User Ratings

In this section, we conducted another empirical study to explore the relationship between the number of design principles implemented in an app and its user ratings. We intended to prove the following hypothesis: *Apps that have implemented more design principles tend to have higher user ratings.*

We counted a design principle as being effectively implemented in the app if there are more positive reviews related to that design principle than negative ones. However, when analyzing the reviews, we noticed that some design principles were not mentioned in the user reviews. For instance, the comments related to "Social support" have been found only in one app (i.e., Diabetic Connect). In such situations, we looked at the description of the app to confirm if the design principle has been implemented in the app. We considered a design principle missing in an app if neither did users mention it in the reviews of the app, nor did we find contents related to the principle in the description of the app.

In order to test our hypothesis, we ran a regression model with the average user ratings of an app (i.e., the variable UserRate) as the dependent variable and the number of design principles effectively implemented in the app (i.e., the variable DesignPrinciplesCount) as the independent variable. We also controlled for the confounding factors including (1) the number of reviews for each app (i.e., the variable ReviewsNumber) and (2) the price of each app (i.e., the variable AppPrice). The descriptive statistics of the dependent variable and the control variables are shown in Table 6.2. A diabetes application has a mean of 140.6 reviews. On average, 5.33 of the 11 design principles have been effectively implemented (with more positive reviews than negative reviews) in an app.

Table 6.2. Descriptive statistics of variables for econometric analysis

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
DesignPrinciplesCount	5.33	1.54	1	7
ReviewsNumber	140.6	116	50	450
AppPrice ($)	2.73	5.09	0	24.99

Table 6.3 shows the Pearson correlations between the variables. We observe that the number of design principles is positively correlated with the number of reviews, which indicates that the apps that implemented more design principles could attract more users and have more user reviews. The number of design principles is also positively correlated with the price of the app, which means that overall, the high-cost apps tend to implement more design principles than the low-cost or free ones. The correlations between the variables are moderate. Hence, there is absence of multicollinearity between the predictors in a regression model.

Table 6.3. Correlation for the variables

	DesignPrinciplesCount	ReviewsNumber	AppPrice
DesignPrinciplesCount	**1.00000**	**0.26310**	**0.38154**
ReviewsNumber		**1.00000**	**0.05874**
AppPrice			**1.00000**

We ran the flowing regression model:

$$\text{UserRate}_i = \alpha_i + \beta_1 \, . \, \text{DesignPrinciplesCount} + \beta_2 \, . \, \text{ReviewsNumber} + \beta_3 \, . \, \text{AppPrice} + \varepsilon_i$$

We found a significant positive effect of the number of design principles (i.e., DesignPrinciplesCount) on the user ratings of the app (see Table 6.4), thus proving the hypothesis that *apps that have implemented more design principles tend to have higher user ratings.* While the impact of the other two variables, ReviewsNumber and AppPrice on user ratings is statistically insignificant, the OLS regression results in an R^2 of 0.6557, suggesting the predictive power of the number of design principles for user ratings.

Table 6.4. Estimation results

Variable	**Parameter estimate**	**Standard Error**	***P*-value**
Intercept	2.28635	0.25243	<0.0001***
DesignPrinciplesCount	0.39464	0.05999	<0.0001***
ReviewsNumber	0.00030575	0.00069849	0.6652
AppPrice	-0.02775	0.01753	0.1255
Number of observations	30		
R-square	0.6557		
Adj R-square	0.6160		

The dependent variable is UserRate. Robust standard errors are listed in parenthesis; *** denote significance at .01.

CHAPTER 7

CONCLUSIONS

This chapter concludes the research project and presents an overview of the practical implications, theoretical and methodological contributions of the study as well as the limitations and future directions.

7.1 Concluding Remarks

This study aims to discover design principles of health behavioral change support systems (BCSSs) through analyze the actual use of these systems using a text analytics approach. This work demonstrates the use of text mining approach to discover design principles of BCSSs leveraging User-Generated Content (UGC) (in terms of online user reviews) as a primary data source. Given the importance of diabetes self-management applications for improving the lives of diabetes patients by leveraging patients' self-care practices, we use mobile applications for diabetes self-management as a problem domain. To evaluate the importance of the design principles discovered, the frequency of each design principle in low stars users' reviews (i.e. users complaints) is calculated. The findings revealed that the design principles form more than 80% of the users complaints. Additionally, which of these principles are the most negatively-perceived by users is computed. Also, our design principles are compared with widely used existing persuasive design principles presented in (Oinas-Kukkonen and Harjumaa 2009) as well as the existing literature of consumer health information technology (CHIT) acceptance and technology acceptance for elderly patients/Telehealth systems.

The findings of our research reveal that some design principles are more important than others. "Effort expectancy", "Self-monitoring", "Informative presentation", "Communication with doctors" and "Integration with Information Systems (IS)" are the most important principles. They are followed by "Integration with medical devices", “Customization”, and “Technical support” that are also critical. “Social support” and “Persuasive messages” are the least important ones according to the user reviews. Moreover, our findings indicate that users are most bothered by issues related to the following design principles: “Technical support”, “Integration with Information systems (IS)”, “Integration with medical devices”, “Effort expectancy”, “Customization”, and “Communication with doctors”. We also proved the significant positive impact of the number of design principles implemented in an app on the app’s user ratings.

7.2 Practical Implications

The findings indicate that the current practice in developing self-care apps stresses a techno-centric approach, focusing primarily on the technical aspects, while treating social and structural design features (such as integration of the apps with other IS components) as secondary and complementary rather than integral to an application. In essence, the design of health apps should connect patients with peers where they can exchange social support and experience, cooperate, and compare their performance. Such connection has a significant importance in persuading users to change their behavior and achieve their goals as they are more likely to perform when they perceive social support and observe others’ performance. It is thus paramount to view diabetes self-management apps as a component within a holistic health system. In this system, the app should enable patients to export and communicate their readings and information with physicians, and it should be integrated with other health apps (i.e., fitness apps) and medical devices such as glucose meters and insulin pump, and other information systems such as mobile devices and server so users can backup and restore their health data.

These results support the integration and interoperability design practice (Pennic 2014), which states that diabetes apps, just like mHealth apps in general, should be designed in a way that allows users to input and access their data through multiple devices from various sources. Ideally, according to (Pennic 2014), diabetes apps would be integrated with external devices, sensors, and other apps, which help users achieve better control of critical health parameters in the management of diabetes (such as blood glucose levels, blood pressure, cholesterol), support the necessary lifestyle changes (weight management, exercise, nutrition) and provide new ways for connecting patients with their physicians. Further, our findings confirmed the personalization design practice (Pennic 2014), which implies that developers of mobile health apps are highly recommended to allow users to choose and customize how data is displayed and what metrics are being measured and what are the optimal levels for these metrics. Organizationally or operationally, the findings of this study present the technical support as an important acceptance factor for these consumer health systems. These findings have implications for practice that can help mobile app developers develop more successful diabetes apps that promote user self-efficacy and sustainable use. In essence, the findings of this study could be integrated into the design phase of the new apps to help developers develop more efficient new apps.

7.3 Theoretical Implications

Theoretically, the findings of this research provide evidence that socio-technical perspective is applicable to the context of health persuasive systems. Particularly, persuasive systems design should move the focus from pure technology to contexts of users' daily life. In fact, understanding user task goals, user interactions and capturing appropriate context are some of the important issues that need to be considered in the design of persuasive computing applications. In this regard, this study develops a socio-technical design principles that encourage the integration and communication between the various components within users' usage context.

This work contributes to existing knowledge base of persuasive systems design by 1) supporting some existing theoretical persuasive systems design principles developed by Oinas-Kukkonen and Harjumaa (2009) and 2) inferring new design principles. Further, since the design principles extracted from users' feedback that reflect users' preferences are likely to influence users' acceptance of these technology, the results also contribute to the literature of users' acceptance of health consumer technology.

7.4 Methodological Implications

Methodologically, this study exploits users' feedback in form of online reviews. In essence, the design of persuasive systems requires understanding of users context, recognizing the intent, event, and strategies for the use of a persuasive system (Oinas-Kukkonen and Harjumaa 2009). In this regard, user involvement is key in persuasive systems which can help shift the focus of innovation from pure technology to the context of daily life (Thackara 2001). We hence developed design principles based on users' reviews. Instead of manually analyzing and coding the reviews, which is time-consuming and subjective, we used text mining, more specifically the LDA algorithm for topic modeling, to automatically extract design features from large amounts of text data. The proposed method particularly pertains to persuasive systems where the intrinsic objective is to persuade users to possibly do things they would otherwise not do or not have an immediate incentive to do, which often leads to the sensitivity and criticality of users' feedback and input. The approach could also be generalized to other systems that share some of these characteristics, for example, educational games that are designed to help users to learn about certain subjects and persuade them to learning.

Further, since self-care apps developers face pressure to continuously refine the quality and value of their apps to meet evolving user expectations and sustain sales, a means of informing these refinements can be through the practice of the proposed method that automatically harvest insights from user reviews, which help developers measure adoption and monitor performance of their current apps as well as competing apps.

7.5 Limitations and Future Steps

Limitations of this research are related to the generalizability of our design principles to other health BCSSs and the evaluation of the topic modeling. Indeed, it is still a challenge to evaluate the results of topic modeling as unsupervised technique for exploratory analysis that is used to discover patterns in the text. It is still an open question for designing a robust evaluation methods so that the user could trust the topics describing text that he or she has never read.

As a future research, we aim to explore the proposed method in other application domains aside than diabetes and further explore the generalizability of the proposed principles for persuasive system design.

REFERENCES

Abraham, C., & Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health psychology, 27*(3), 379.

Aggarwal, R., Gopal, R., Gupta, A., & Singh, H. (2012). Putting money where the mouths are: The relation between venture financing and electronic word-of-mouth. *Information Systems Research*, *23*(3-part-2), 976-992.

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

Ajzen, I., & Fishbein, M. (1975). Belief, attitude, intention and behavior: An introduction to theory and research. Reading, MA: Addison-Wesley.

American Diabetes Association (2016). Standards of Medical Care in Diabetes--2016. *Diabetes Care*, *39*(Supplement 1).

Archak, N., Ghose, A., & Ipeirotis, P. G. (2011). Deriving the pricing power of product features by mining consumer reviews. *Management Science*, *57*(8), 1485-1509.

Azzopardi, L., Girolami, M., & van Risjbergen, K. Investigating the relationship between language model perplexity and IR precision-recall measures. In *Proceedings of the 26th annual international ACM SIGIR conference on Research and development in informaion retrieval, 2003* (pp. 369-370): ACM

Bakhouya, M. Ubiquitous and pervasive computing: architectures and protocols for applications design. In *Proceedings of the 3rd workshop on Agent-oriented software engineering challenges for ubiquitous and pervasive computing, 2009* (pp. 1-2): ACM

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review, 84*(2), 191-215.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*: Prentice-Hall, Inc.

Bandura, A. (1994). Self-efficacy. In: V.S. Ramachaudran (ed). *Encyclopedia of human behavior* (Vol. 4, pp. 71–81). New York: Academic Press.

Bao, Y., & Datta, A. (2014). Simultaneously discovering and quantifying risk types from textual risk disclosures. *Management Science, 60*(6), 1371-1391.

Barak, A., Klein, B., & Proudfoot, J. G. (2009). Defining internet-supported therapeutic interventions. *Annals of Behavioral Medicine, 38*(1), 4-17.

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with Computers, 23*(1), 4-17.

Berg, M., Langenberg, C., vd Berg, I., & Kwakkernaat, J. (1998). Considerations for sociotechnical design: experiences with an electronic patient record in a clinical context. *International journal of medical informatics, 52*(1), 243-251.

Blei, D. M. (2012). Probabilistic topic models. *Communications of the ACM, 55*(4), 77-84.

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent dirichlet allocation. *the Journal of machine Learning research, 3,* 993-1022.

Chang, J., Gerrish, S., Wang, C., Boyd-Graber, J. L., & Blei, D. M. Reading tea leaves: How humans interpret topic models. In *Advances in neural information processing systems*, *2009* (pp. 288-296)

Chatterjee, S., & Price, A. (2009). Healthy living with persuasive technologies: framework, issues, and challenges. *Journal of the American Medical Informatics Association, 16*(2), 171-178.

Cherns, A. (1976). The Principles of Sociotechnical Design1. *Human relations, 29*(8), 783-792.

Cherns, A. (1987). Principles of sociotechnical design revisted. *Human relations, 40*(3), 153-161.

Chevalier, J. A., & Mayzlin, D. (2006). The effect of word of mouth on sales: Online book reviews. *Journal of marketing research, 43*(3), 345-354.

Chomutare, T., Fernandez-Luque, L., Årsand, E., & Hartvigsen, G. (2011). Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines. *Journal of medical Internet research, 13*(3).

Cimperman, M., Brenčič, M. M., Trkman, P., & Stanonik, M. d. L. (2013). Older adults' perceptions of home telehealth services. *Telemedicine and e-Health, 19*(10), 786-790.

Clegg, C. W. (2000). Sociotechnical principles for system design. *Applied ergonomics, 31*(5), 463-477.

Compeau, D. R., & Higgins, C. A. (1995). Computer self-efficacy: Development of a measure and initial test. *MIS quarterly, 19*(2), 189-211.

Cooper, J., Gencturk, N., & Lindley, R. A. (1996). A sociotechnical approach to smart card systems design: an Australian case study. *Behaviour & Information Technology, 15*(1), 3-13.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly, 13*(3), 319-340.

Dewan, S., & Ramaprasad, J. (2014). Social media, traditional media, and music sales. *MIS quarterly, 38*(1), 101-121.

Duan, W., Yu, Y., Cao, Q., & Levy, S. (2016). Exploring the Impact of Social Media on Hotel Service Performance: A Sentimental Analysis Approach. *Cornell Hospitality Quarterly, 57*(3), 282-296.

El-Gayar, O., Sarnikar, S., & Wahbeh, A. On the Design of IT-Enabled Self-Care Systems: A Socio-technical Perspective. In *System Sciences (HICSS), 2013 46th Hawaii International Conference on, 2013a* (pp. 2484-2493): IEEE

El-Gayar, O., Timsina, P., Nawar, N., & Eid, W. (2013b). Mobile applications for diabetes self-management: status and potential. *Journal of diabetes science and technology, 7*(1), 247-262.

El-Gayar, O., Timsina, P., Nawar, N., & Eid, W. (2013c). A systematic review of IT for diabetes self-management: are we there yet? *International journal of medical informatics, 82*(8), 637-652.

Eysenbach, G. (2000). Recent advances: Consumer health informatics. *BMJ: British Medical Journal, 320*(7251), 1713-1716.

Festinger, L. (1957). *A theory of cognitive dissonance*. Stanford, California: Stanford university press.

Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., et al. (2013). The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLoS med, 10*(1), e1001362.

Geuens, J., Swinnen, T. W., Westhovens, R., De Vlam, K., Geurts, L., & Abeele, V. V. (2016). A Review of Persuasive Principles in Mobile Apps for Chronic Arthritis Patients: Opportunities for Improvement. *JMIR mHealth and uHealth, 4*(4).

Ghose, A., & Ipeirotis, P. G. (2011). Estimating the helpfulness and economic impact of product reviews: Mining text and reviewer characteristics. *IEEE Transactions on Knowledge and Data Engineering, 23*(10), 1498-1512.

Gibbons, M. C., Wilson, R. F., Samal, L., Lehmann, C. U., Dickersin, K., Lehmann, H. P., et al. (2009). Impact of consumer health informatics applications. *Evidence Reports/Technology Assessments* (Vol. 9).

Goh, K.-Y., Heng, C.-S., & Lin, Z. (2013). Social media brand community and consumer behavior: Quantifying the relative impact of user-and marketer-generated content. *Information Systems Research*, *24*(1), 88-107.

Graml, T., Loock, C.-M., Baeriswyl, M., & Staake, T. Improving residential energy consumption at large using persuasive systems. In *ECIS, 2011*

Guo, Y., Barnes, S. J., & Jia, Q. (2017). Mining meaning from online ratings and reviews: Tourist satisfaction analysis using latent dirichlet allocation. *Tourism Management, 59*, 467-483.

Gustafson, D. H., Hawkins, R. P., Boberg, E. W., McTavish, F., Owens, B., Wise, M., et al. (2002). CHESS: 10 years of research and development in consumer health informatics for broad populations, including the underserved. *International journal of medical informatics, 65*(3), 169-177.

Haddi, E., Liu, X., & Shi, Y. (2013). The role of text pre-processing in sentiment analysis. *Procedia Computer Science, 17*, 26-32.

Hanssen, G. K. (2012). A longitudinal case study of an emerging software ecosystem: Implications for practice and theory. *Journal of Systems and Software*, *85*(7), 1455-1466.

Harjumaa, M., & Oinas-Kukkonen, H. An analysis of the persuasiveness of smoking cessation web sites. In *Proceedings of the Second International Symposium on Medical Information and Communication Technology, Oulu: Finland, 2007*

Harjumaa, M., Segerståhl, K., & Oinas-Kukkonen, H. Understanding persuasive software functionality in practice: a field trial of polar FT60. In *proceedings of the 4th international conference on persuasive technology, 2009* (pp. 2): ACM

Hevner, V. A., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly, 28*(1), 75-105.

Hu, N., Koh, N. S., & Reddy, S. K. (2014). Ratings lead you to the product, reviews help you clinch it? The mediating role of online review sentiments on product sales. *Decision support systems, 57*, 42-53.

Igbaria, M., Guimaraes, T., & Davis, G. B. (1995). Testing the determinants of microcomputer usage via a structural equation model. *Journal of management information systems*, 87-114.

Jackson, S. (2011). Most successful health apps keep consumer preferences in mind. http://www.fiercehealthcare.com/mobile/most-successful-health-apps-keep-consumer-preferences-mind. Accessed October 24 2016.

Jung, Y., Hur, C., Jung, D., & Kim, M. (2015). Identifying key hospital service quality factors in online health communities. *Journal of medical Internet research, 17*(4), e90.

Karppinen, P., Lehto, T., Oinas-Kukkonen, H., Pätiälä, T., & Saarelma, O. (2014). Using hermeneutics to uncover anomalies for non-adoption of behavior change support systems.

Karppinen, P., Oinas-Kukkonen, H., Alahäivälä, T., Jokelainen, T., Keränen, A.-M., Salonurmi, T., et al. (2016). Persuasive user experiences of a health Behavior Change Support System: A 12-month study for prevention of metabolic syndrome. *International journal of medical informatics*.

Kelders, S. M., Kok, R. N., Ossebaard, H. C., & Gemert-Pijnen, J. E. V. (2012). Persuasive System Design Does Matter: A Systematic Review of Adherence to Web-Based Interventions. *Journal of medical Internet research, 14*(6), e152.

Khalid, H., Shihab, E., Nagappan, M., & Hassan, A. (2014). What do mobile app users complain about? A study on free iOS apps. *Software, IEEE, PP*(99).

Kim, W. G., Li, J. J., & Brymer, R. A. (2016). The impact of social media reviews on restaurant performance: The moderating role of excellence certificate. *International Journal of Hospitality Management, 55*, 41-51.

Kim, W. G., Lim, H., & Brymer, R. A. (2015). The effectiveness of managing social media on hotel performance. *International Journal of Hospitality Management, 44*, 165-171.

Kuipers, D. A., Wartena, B. O., Dijkstra, B. H., Terlouw, G., van t Veer, J. T., van Dijk, H. W., et al. (2016). iLift: A health behavior change support system for lifting and transfer techniques to prevent lower-back injuries in healthcare. *International journal of medical informatics*.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *biometrics*, 159-174.

Langrial, S., Lehto, T., Oinas-Kukkonen, H., Harjumaa, M., & Karppinen, P. Native Mobile Applications For Personal Well-Being: A Persuasive Systems Design Evaluation. In *PACIS, 2012* (pp. 93)

Laurie, J., & Blandford, A. (2016). Making time for mindfulness. *International journal of medical informatics*.

Leavitts, H. (1964). Applied Organisation Change in Industry: Structural, Technical and Human Approaches. *New Perspectives in Organisational Research, John Wiley*.

Lehto, T., Oinas-Kukkonen, H., Pätiälä, T., & Saarelma, O. Consumers' Perceptions of a Virtual Health Check: an Empirical Investigation. In *ECIS, 2012* (pp. 154)

Lehto, T., Oinas-Kukkonen, H., Pätiälä, T., & Saarelma, O. (2013). Virtual health coaching for consumers: a persuasive systems design perspective. *International Journal of Networking and Virtual Organisations 4, 13*(1), 24-41.

Liang, T.-P., Li, X., Yang, C.-T., & Wang, M. (2015). What in consumer reviews affects the sales of mobile apps: A multifacet sentiment analysis approach. *International Journal of Electronic Commerce, 20*(2), 236-260.

Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American psychologist, 57*(9), 705-717.

Lyytinen, K., & Newman, M. (2008). Explaining information systems change: a punctuated socio-technical change model. *European Journal of Information Systems, 17*(6), 589-613.

Matthews, J., Win, K. T., Oinas-Kukkonen, H., & Freeman, M. (2016). Persuasive Technology in Mobile Applications Promoting Physical Activity: a Systematic Review. *Journal of medical systems, 40*(3), 1-13.

Mclean, V. (2011). Motivating Patients to Use Smartphone Health Apps. http://www.consumer-health.com/press/2008/NewsReleaseSmartPhoneApps.php. Accessed February 15 2015.

Mei, L., & Easterbrook, S. Evaluating user-centric adaptation with goal models. In *Software Engineering for Pervasive Computing Applications, Systems, and Environments, 2007. SEPCASE'07. First International Workshop on, 2007* (pp. 6-6): IEEE

Mumford, E. (2006). The story of socio-technical design: reflections on its successes, failures and potential. *Information Systems Journal, 16*(4), 317-342.

Murray, E., Burns, J., See, T. S., Lai, R., & Nazareth, I. (2005). Interactive Health Communication Applications for people with chronic disease. *Cochrane Database Syst Rev, 4*.

Neubeck, L., Coorey, G., Peiris, D., Mulley, J., Heeley, E., Hersch, F., et al. (2016). Development of an integrated e-health tool for people with, or at high risk of, cardiovascular disease: The Consumer Navigation of Electronic Cardiovascular Tools (CONNECT) web application. *International journal of medical informatics*.

Oinas-Kukkonen, H. (2010). The discipline of information systems: A natural strategic alliance for web science.

Oinas-Kukkonen, H. (2013). A foundation for the study of behavior change support systems. *Personal and ubiquitous computing, 17*(6), 1223-1235.

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

Or, C. K., & Karsh, B.-T. (2009). A systematic review of patient acceptance of consumer health information technology. *Journal of the American Medical Informatics Association, 16*(4), 550-560.

Or, C. K., Karsh, B.-T., Severtson, D. J., Burke, L. J., Brown, R. L., & Brennan, P. F. (2011). Factors affecting home care patients' acceptance of a web-based interactive self-management technology. *Journal of the American Medical Informatics Association, 18*(1), 51-59.

Or, C. K., & Tao, D. (2014). Does the use of consumer health information technology improve outcomes in the patient self-management of diabetes? A meta-analysis and narrative review of randomized controlled trials. *International journal of medical informatics, 83*(5), 320-329.

Peek, S. T., Wouters, E. J., van Hoof, J., Luijkx, K. G., Boeije, H. R., & Vrijhoef, H. J. (2014). Factors influencing acceptance of technology for aging in place: a systematic review. *International journal of medical informatics, 83*(4), 235-248.

Pennic, F. (2014). 7 Best Practices for Developing Successful Diabetes Mobile Apps. http://hitconsultant.net/2014/03/03/developing-behavior-changing-diabetes-mobile-apps/?trendmd-shared=0. Accessed October 25 2016.

Petty, R., & Cacioppo, J. (1986). Communication and persuasion: Central and peripheral routes to attitude change. New York:: Springer-Verlag.

Phillips, P., Barnes, S., Zigan, K., & Schegg, R. (2016). Understanding the Impact of Online Reviews on Hotel Performance An Empirical Analysis. *Journal of Travel Research*, 0047287516636481.

Research2Guidance (2014). Diabetes App Market Report 2014. https://research2guidance.com/wp-content/uploads/2015/08/Diabetes-App-Market-Report-2014-Preview.pdf. Accessed October 26, 2016 2016.

Research2guidance (2016). mHealth App Developer Economics 2016. http://research2guidance.com/product/mhealth-app-developer-economics-2016/. Accessed October 27 2016.

Ruland, C. M., Maffei, R. M., Børøsund, E., Krahn, A., Andersen, T., & Grimsbø, G. H. (2013). Evaluation of different features of an eHealth application for personalized illness management support: cancer patients' use and appraisal of usefulness. *International journal of medical informatics, 82*(7), 593-603.

Sarnikar, S., El-Gayar, O., & Wahbeh, A. A process model for eliciting requirements of socio-technical systems. In *the 20th Americas Conference on Information Systems (AMCIS '14), Savanah, 2014*: AIS

Scacchi, W. (2004). Socio-technical design. *The encyclopedia of human-computer interaction, 1*, 656-659.

Segerståhl, K., Kotro, T., & Väänänen-Vainio-Mattila, K. (2010). Pitfalls in persuasion: how do users experience persuasive techniques in a web service? In *Persuasive Technology* (pp. 211-222): Springer.

Singh, J., Lutteroth, C., & Wünsche, B. C. Taxonomy of usability requirements for home telehealth systems. In *Proceedings of the 11th International Conference of the NZ Chapter of the ACM Special Interest Group on Human-Computer Interaction, 2010* (pp. 29-32): ACM

Strecher, V. (2007). Internet methods for delivering behavioral and health-related interventions (eHealth). *Annu. Rev. Clin. Psychol., 3*, 53-76.

Tang, L., Yu, Z., Zhou, X., Wang, H., & Becker, C. (2011). Supporting rapid design and evaluation of pervasive applications: challenges and solutions. *Personal and ubiquitous computing, 15*(3), 253-269.

Thackara, J. (2001). The design challenge of pervasive computing. *Interactions, 8*(3), 46-52.

Thomas, C. (2013a). An open letter to mobile health app developers and their funders. https://ethicalnag.org/2013/04/24/open-letter-health-app-developers-funders/. Accessed October 24 2016.

Thomas, C. (2013b). Why 74% of smartphone apps are dropped by the 10th use. https://ethicalnag.org/2013/07/06/phone-app-users-drop-out/. Accessed October 24 2016.

Torning, K., & Oinas-Kukkonen, H. Persuasive system design: state of the art and future directions. In *Proceedings of the 4th international conference on persuasive technology, 2009* (pp. 30): ACM

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly, 27*(3), 425-478.

Wildeboer, G., Kelders, S. M., & van Gemert-Pijnen, J. E. (2016). The relationship between persuasive technology principles, adherence and effect of web-Based interventions for mental health: A meta-analysis. *International journal of medical informatics*.

Xiang, Z., Schwartz, Z., Gerdes, J. H., & Uysal, M. (2015). What can big data and text analytics tell us about hotel guest experience and satisfaction? *International Journal of Hospitality Management, 44*, 120-130.

Xu, Y., Armony, M., & Ghose, A. (2016). The Effect of Online Reviews on Physician Demand: A Structural Model of Patient Choice. *Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2778664*.

Yang, J., Sarathy, R., & Lee, J. (2016). The effect of product review balance and volume on online Shoppers' risk perception and purchase intention. *Decision support systems, 89*, 66-76.

Yoganathan, D., & Kajanan, S. Persuasive Technology for Smartphone Fitness Apps. In *PACIS, 2013* (pp. 185): Citeseer

Yoganathan, D., & Kajanan, S. (2014). What Drives Fitness Apps Usage? An Empirical Evaluation. In *Creating Value for All Through IT* (pp. 179-196): Springer.

Yu, Y., Duan, W., & Cao, Q. (2013). The impact of social and conventional media on firm equity value: A sentiment analysis approach. *Decision support systems*, *55*(4), 919-926.

Zhang, Z., Guo, C., & Goes, P. (2013). Product comparison networks for competitive analysis of online word-of-mouth. *ACM Transactions on Management Information Systems (TMIS)*, *3*(4), 20.

Zhou, J., Gilman, E., Palola, J., Riekki, J., Ylianttila, M., & Sun, J. (2011). Context-aware pervasive service composition and its implementation. *Personal and ubiquitous computing*, *15*(3), 291-303.

APPENDICES

APPENDIX A: THE NAMES OF THE 30 DIABETES APPLICATIONS USED

App Name	Category
Diabetes App - blood sugar control, glucose tracker and carb counter	Medical
Glucose Buddy - Diabetes Logbook Manager wsyncing, Blood Pressure, Weight Tracking	Medical
Diabetes Tracker with Blood Glucose/Carb Log by MyNetDiary	Medical
Diabetes App Lite - blood sugar control, glucose tracker and carb counter	Medical
Diabetes in Check: Coach, Blood Glucose & Carb Tracker	Medical
Diabetes Log	Health & Fitness
Track3 - Diabetes Planner, Diabetes Glucose Logbook, Diabetes Tracker, Carb Counter	Medical
Glucose Companion Free	Medical
Blood Sugar Diabetes Control	Health & Fitness
Diabetik	Medical
Healthsome G for Glucose	Medical
WaveSense Diabetes Manager	Health & Fitness
Glucose Companion By Maxwell Software	Medical
LogFrog DB Lite - A Leap in Diabetes Management	Health & Fitness
iBGStar® Diabetes Manager	Medical

Diabetes Pedometer with Glucose & Food Diary, Weight Tracker, Blood Pressure Log and Medication Reminder by Pacer	Medical
Diabetes Pilot Classic	Health & Fitness
Diabetes Pal App: Logbook Manager for Blood Glucose, A1c, Nutrition, Medication, Weight, Blood Pressure Analysis + Withings and BodyMedia	Medical
LogFrog DB - A Leap in Diabetes Management	Health & Fitness
Diabetes in Pregnancy - Gestational Diabetes Logbook and Manager	Medical
Diamedic	Health & Fitness
BGluMon - Blood Glucose Monitor	Medical
Diabetes - DailyDiab	Medical
Diabetes Logbook by mySugr	Medical
Glucose Buddy Pro : Diabetes Managing Logbook w/ Blood Pressure & Weight Tracking	Medical
Glooko	Medical
Glucose-Charter	Medical
Diabetic Connect	Social networking
Health Tracker & Manager for iPhone	Health & Fitness
myMedtronic Connect	Health & Fitness