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Discovering Design Principles for Persuasive Systems: A Grounded Theory and Text Mining Approach

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Abstract

Persuasive systems aim to change users' behavior and lifestyle. These systems have been gaining popularity with the proliferation of wearable devices and recent advances in information technology. In that regard, recent research aims at identifying system design principles that are specific to persuasive systems. In this article we extend the existing literature by discovering design principles for persuasive systems from a systematic analysis of users feedback from the actual use of persuasive systems.

Specifically, we use grounded theory and text mining (topic modeling) to extract design concepts from online user reviews of mobile diabetes applications. Overall, the results extend existing findings by highlighting the necessity of going beyond the techno-centric approach used in current practice and incorporating the social and structural features into persuasive system design.

1. Introduction

Persuasive systems are "computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception" [1]. More recently, Oinas-Kukkonen [2] suggested the concept of a behavioral change support systems (BCSS), which refers to information systems that are developed for the purpose of behavioral change. A BCSS is "a socio-technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception" [2]. This definition includes three potential successful voluntary outcomes for a BCSS: the *formation, alteration or reinforcement of attitudes, behaviors, or complying* [2]. These promising outcomes make BCSS especially useful in certain areas such as healthcare, where these systems could be leveraged to motivate people toward healthy behavior and then help them to achieve their goals better [1, 2].

Past research on persuasive systems 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 persuasive systems [3]. For instance, Kelders, et al. [4] reviewed 101 articles on health interventions and demonstrated that intervention characteristics and persuasive design affect adherence to web-based interventions. Such theoretic studies undoubtedly help inform the understanding of persuasive technology. However, they seem to be limited with respect to their application to persuasive system design and development [5]. Other research aimed at developing design principles for persuasive systems. For example, Oinas-Kukkonen and Harjumaa [3] 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 persuasive systems.

In that regard, the grounded theory method developed by Glaser and Strauss [6] as 'the discovery of theory from data-systematically obtained and analyzed in social research'. This definition implies that a grounded theory researcher does not start with a set of hypotheses to be tested. Rather, the concepts and the theory are supposed to emerge from the data. To make sure that the concepts do indeed emerge from the data, as a general rule, grounded theory researchers should ensure that they have no preconceived theoretical ideas before conducting their research [7].

The goal of our research is to discover design principles for persuasive systems based on a systematic analysis of user feedback following a grounded theory approach. Investigating user feedback is particularly necessary for persuasive system design since user acceptance/adherence is the central theme of persuasive technology. Nowadays, the advances of

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Web 2.0 technologies have enabled consumers to easily and freely exchange opinions on products and services on an unprecedented scale in real time. Online user review systems provide us with one of the most powerful channels for extracting user feedback.

In this study, we focus on one widely used type of persuasive technology, diabetes mobile applications, and develop design principles based on user reviews. The results of the meta-analysis of randomized controlled trials conducted by Or and Tao [10] indicates that the use of consumer health information technologies (CHITs) in supporting diabetes self-management brings about potential benefits for diabetic patients' self-management. These technologies have the potential to release patients from high hospital care costs, improve healthcare convenience, promote communication between clinician and patients, and empower patients to gain more control of their disease care [10]. In the last decade, the exponential growth in smartphone technology have resulted in opportunities for improved diabetes self-management [11]. Health-related mobile applications (usually referred to as apps) run over smartphones hold promise for healthy behavior change [12] and help reduce the risk of long-term disability. However, healthcare apps as persuasive technology have not been used to their fullest strength. Only 26% of healthcare apps are downloaded with only one use and 74% of them drop out by the tenth use [13]. More research need to be performed to explore the efficacy of healthcare apps as patients adherence tools [13]. Particularly, it is important to develop design principles for persuasion to support one's diabetes self-management.

In this research, we propose to use grounded theory as the underlying research methodology to discover design principles. We compare our data-grounded design principles with the design principles developed by Oinas-Kukkonen and Harjumaa [3]. Our research is intended to discover design principles as well as provide empirical basis for the existing design principles. Moreover, given the huge amounts of diabetes apps review data available online, we seek to apply text mining as an objective content analysis approach within the grounded theory framework to automatically extract and analyze the contents of user reviews.

From a theoretical perspective, this research contributes to the nascent literature pertaining to the design and development of persuasive systems. From a methodological perspective, the research demonstrates the viability of text mining, specifically topic mining as an alternative content analysis mechanism for grounded theory research. Last but not least, from a practitioners' perspective, the research further contributes to the fledging persuasive system development industry, particularly with the proliferation of wearable devices.

The remainder of the article is organized as follows; the following section presents a brief overview of persuasive systems design. Section 3 details the research methodology, while section 4 presents the results. The last section provides a brief discussion and concludes the paper with directions for future research.

2. Related work and background

The process of IT design should be understood as the development of sociotechnical configurations [14]. Significant research has been conducted to develop sociotechnical design principles for IT systems. Berg, et al. [14] present three considerations of design based on their experience with an Electronic Patient Record (ERP) on an Intensive Care Unit (ICU): (1) Structure is a sine qua non for the functioning of IT, but it should be empirically informed. (2) The systems should support work, not generate it. To achieve that it is necessary to incorporate structure in the ERP. (3) User involvement in the whole design process is a sine qua non. Baxter and Sommerville [8] refer to socio-technical systems design (STSD) methods as "an approach to designing that considers human, social and organizational factors, as well as technical factors in the design of organizational systems". In this context, organizational refers to company or business related factors while social refers to factors related to the relationships between people who interact together within and across organizations [8]. 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" [15]. Toward this objective, Cherns [16] identifies nine principles for socio-technical design. Clegg [17] later presents a revised set of these sociotechnical principles to guide system design and to consider the potential roles and contributions of such principles. However, the weakness of these design principles is that they cannot be easily transformed into software requirements and further implemented as actual system features of persuasive systems.

The sociotechnical design method has also been applied to the area of persuasive systems. The most important study that develops sociotechnical design principles in this field is probably the one conducted by Oinas-Kukkonen and Harjumaa [3], which 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.

In another study, Torning and Oinas-Kukkonen [18] 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, Kaptein, et al. [19] demonstrated the importance of involving users in the selection of appropriate persuasive strategy as well as selecting a single correct strategy for a given context.

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. Chomutare, et al. [20] 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. [21] 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 [3]. The study indicates that the current mobile apps often lack features related to human-computer dialogue and social support. Recently, Yoganathan and Kajanan [22] 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.

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 such systems. Such User-Centered Design (UCD) approach that is based on the active involvement of users is widely considered the key to produce usefulness and usability [23]. A systematic literature review of research regarding patient acceptance of Consumer Health Information Technology (CHIT) conducted by Or and Karsh [24] revealed that few studies tested the impact of organizational or environmental factors on acceptance. To address this "gap" in existing research, we aim to use grounded theory procedures to develop design principles for persuasive systems based on online user reviews.

3. Research methodology and design

We use the grounded theory method as our primary research methodology [6]. Following the general grounded theory framework proposed in [25], our study involves four main phases: *data collection*, *open coding*, *axial coding and ontology building*, and *selective coding*. The following figure shows the stages and the results associated with each.

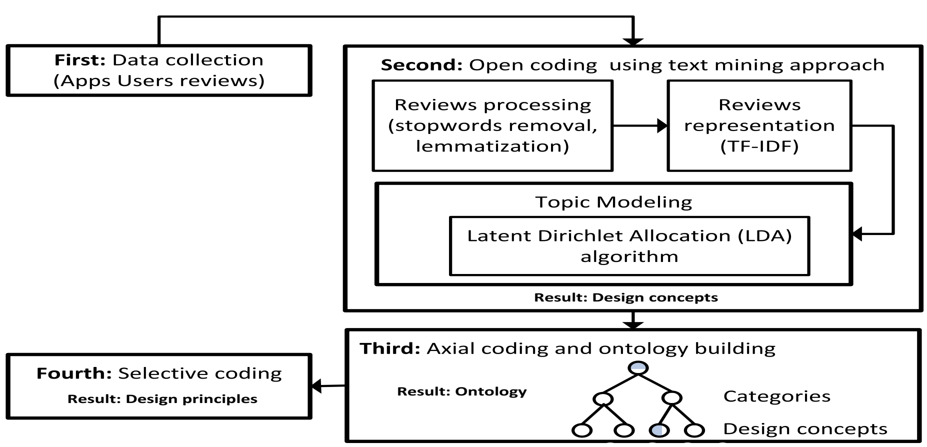

Figure 1. Overview of our grounded theory approach

The three basic elements of grounded theory are *concepts*, *categories*, and *propositions* [25]. Concepts are the basic units of analysis since it is from conceptualization of data [26]. The second element of grounded theory, categories, is defined as follow [27]: "Categories are higher in level and more abstract than the concepts they represent. They are generated through the same analytic process of making comparisons to highlight similarities and differences that is used to produce lower level concepts. Categories are the 'cornerstones' of developing theory. They provide the means by which the theory can be integrated".

The third element of grounded theory is propositions that indicate generalized relationships between a category and its concepts and between discrete categories [25].

3.1. Data collection

The data for this study was collected from Apple iTunes store. 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 has to meet two requirements: 1) it must provide functions to support diabetes self-management, and 2) it should have at least 35 reviews. 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. The following table provides the descriptive statistics of the collected data.

Table1. Summary of apps data

Count of apps	The user reviews				
	Count	Mean	Std Dev	Max	Min
30	4,218	140.6	122.5	450	35

3.2. Open coding using text mining approach

Data analysis is central to grounded theory by which theories are built from data [27]. It involves generating concepts through the process of coding which represents the operations by which data are broken down, conceptualized, and put back together in new ways [25]. There are three analytic types of coding in grounded theory: *open coding*, *axial coding*, and *selective coding* [26].

Open coding is the part of analysis that deals with the labeling and categorizing of phenomena found in the text [25]. The results of open coding as descriptive process are concepts, which form the basic building blocks in grounded theory construction [7]. Whereas open coding comes up with concepts, axial coding represents the process of developing main categories and their sub-categories. Lastly, selective coding that deals with the integration of the categories that have been developed to build theoretical framework [26]. Since concepts and categories emerge from qualitative text data, there are common grounds and possibly missing links between grounded theory and text mining. Although manual content analysis is used in most grounded theory research, content analysis is only one of multiple methods for acquiring and analyzing data. Text mining and grounded theory are epistemologically compatible, and text mining enables us to automatically extract concepts and theories from "big data" that are prevalent in today's web 2.0 applications. Text mining is a process of extracting useful information from document collections through the identification and exploration of interesting patterns [28]. In alignment with grounded theory, in which researchers must put aside any preconceptions, text mining requires open-mindedness of the miners in a way that enables the categories to be emerged from the data [29]. Text mining allows grounded theory researchers to perform the process of coding using automated algorithms and thus prevents them from being "contaminated" by any preconceptions. In this sense, text mining allows researchers to objectively extract meaningful pieces of information out of unstructured qualitative text data, thus avoiding the subjectivity and many uncontrollable factors of the manual coding, such as fatigue, boredom, varying emotional states, and carelessness [29].

Interestingly, although the many common attributes between content analysis (i.e. manual coding) and text mining, only a few articles that link both can be found [29]. For example, Lin, et al. [30] developed a text mining system to facilitate the automatic coding process of student discussions in course management systems. They found that text mining is a suitable replacement of content analysis that requires intensive labor work. Likewise, in this research, we seek to apply text mining technique to facilitate the coding of user reviews of the diabetes applications. By doing that, we wish to emphasize the potential of grounded theory and text mining, more specifically topic modeling, to improve the quality of the concepts and categories used in the analysis.

3.2.1 Latent Dirichlet Allocation (LDA) for topic modeling

In our study, we used a type of text mining technology called topic modeling. Topic models are statistical-based algorithms for discovering the main themes that pervade a large and unstructured collection of documents [31]. Topic models allow us to summarize textual data at a scale that is impossible to be tackled by human annotation [31]. In alignment with grounded theory, 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 [31]. In this study, we adopted the Latent Dirichlet Allocation (LDA) algorithm, the most widely used topic modeling approach, to analyze the reviews of diabetes apps users.

The objective of the LDA as an unsupervised machine learning technique is to automatically discover hidden topics from a collection of documents. The central computational problem for LDA is to infer the latent topic structure from the observed documents [31]. The distinguishing feature of LDA is that although all documents in the collection have the same set of topics, each document express those topics in different proportion [31]. To illustrate the results of LDA, Let D={d_1, d_2, …, d_n} the set of documents in the collection, T={t_1, t_2, …, t_m} the set of extracted topics and W={w_1, w_2, …, w_k} the number of words in each topic. The first result is the $D \times T$ matrix with $n \times m$ size, where the weight $w_{i,j}$ is the association between a document d_i and a topic t_j. In our case, the documents are user reviews for diabetes apps. We constructed a $W \times T$ matrix with $k \times m$ size, where the weight $w_{i,j}$ is the association between a word w_i and a topic t_j.

To extract the latent design concepts from user reviews of diabetes self-care apps using the LDA algorithm, we integrated the reviews of all apps in a big data file and treat each user review as one document. The result of this step is a file with 4,218 reviews. Then, based on a trial-and-error process, we fitted a 10-topics LDA model with 10 iterations after removing stop words, performing lemmatization (i.e., converting words in inflected forms (e.g., plural nouns and past-tense verbs) to their original forms), and representing each document using the well-known TF-IDF weighting scheme [32]. As a result of this step, each review is associated with ten different topics with a certain probability and that topics are associated with different words with a certain probability. An example of a topic extracted is shown in the following Table 2 which describes users' experience when use diabetes apps to track blood sugar and glucose.

Table2. Example of a topic structure

Tracking
'0.024*help + 0.024*app + 0.021*track + 0.016*diabet + 0.015*blood + 0.014*sugar + 0.014*use + 0.013*great + 0.011*easi + 0.010*glucos'

It shows that the topic is represented as a linear function of words with different weights. The design concept assigned to this topic is "Tracking". To interpret and assign concepts to topics extracted, all researchers independently created the design concepts and then compared the results.

3.3. Axial coding and ontology building

Open coding with topic modeling enables us to extract design concepts, the bottom-level units of analysis in grounded theory. We can then conduct axial coding, which refers to the process of developing main categories and their sub-categories [25]. During this stage, we followed a bottom-up approach to develop an ontology that illustrates the structure of the design concepts extracted. First, we put the primitive concepts discovered from all apps, which represent design features of diabetes apps at level 1 in the ontology. Second, we followed the procedure below to group these low level design features into more general categories. These general categories represent the *design principles,* which lie at the second level of the ontology.

Input: The primitive design concepts at level 1 in the ontology
Output: The design principles at level 2 in the ontology

For each concept:
If it relates to *discussion forums*, *blogs*, or *online community*:
Put it under *Peers Community Support*
Else If it relates to *reminders* or *alerts*:
Put it under *Persuasive Messages* [3]
Else If it relates to *providing means for users to track their performance or status*:
Put it under *Self-monitoring* [3]
Else If it relates to *presenting users' data in a way that is readable and depicting users' performance*:
Put it under *Informative Presentation* [33]
Else If it relates to *the degree of ease associated with the use of the system and logging users' information regarding their status or performance* :
Put it under *Effort Expectancy* [34]
Else If it relates to *an external element in users' context of using the system*:
Put it under *Connection with supporting elements in user's context*

3.4. Selective coding

In grounded theory, selective coding refers to the integration of the categories that have been developed during the axial coding to form the theoretical framework [26]. During this stage, we followed the procedure below to group the design principles at level two into more generic theoretical dimensions, which are placed at the third level of the ontology. These dimensions form the theoretical framework for the design of diabetes self-care applications.

Input: The design principles at level 2 in the ontology
Output: The generic theoretical dimensions at level 3 in the ontology
For each design principle:
If it supports the carrying out of one of the user's primary tasks:
Put it under *Technical Dimension* [8, 15, 16]
Else If it leverages social facilitation and peer-support:
Put it under *Social Dimension* [8, 15, 16]
Else If it supports the connection with supporting elements in users context:
Put it under *Structural Dimension* [14]

4. Results and Discussion

In this section, we provide the results obtained from the three grounded theory stages: *open coding*, *axial coding* and *selective coding.*

4.1. Open coding results

Table 3 illustrates the result of a 10-topic LDA model. For each topic, the top-10 weighted words in its vocabulary distribution are listed. We add a descriptive word to each topic at the top of Table 3 to represent the major design concept each topic is talking about. Table 4 provides multiple evidences from the data about each concept.

Table3. The design concepts

Tracking	Data entry	Logs manipulation	Graphs	Alert	Forum	Server	Insulin supply	Doctors	Mobile devices
help	app	better	noth	app	connect	app	entri	great	meter
app	time	use	need	alert	everytim	data	enter	use	pound
track	data	app	everyon	work	fun	use	goe	easi	password
diabet	enter	time	app	good	short	time	edit	app	bmi
blood	use	updat	nice	major	place	server	app	love	app
sugar	entri	love	peopl	thank	forum	updat	pump	inform	sync
use	day	log	ui	great	peopl	support	educ	like	time
great	work	enter	truli	record	support	sync	won	doctor	ipad
easi	need	track	graph	help	friendli	day	past	email	iphon
glucos	doesn	diabet	fantast	password	educ	fix	basal	provid	unless

Table 4. The design concepts with evidence from the data

Design concepts	Evidence from the data
Tracking	-The app makes keeping track of glucose levels, carb intake, and medicine I took -Tracking blood glucose -Keep track of carbs -Track my blood sugar -Keep track of all glucose, weight
Graphs	-Reports that include multiple data on one report would be great -See better graphs -Graphs are strange to read -Doctors office can read the data
Data entry	-The entries are easy and convenient -New custom food entries cannot be edited -Delete the glucose reading before entering a new one
Logs manipulation	-Keeps a detailed log of all Vidal info -Used the logs to show my doctor -Not being able to log in taking meds -I delete large groups of data at one time -Erase previous BG entries
Alerts	-Just like my new REVEL pump alerts me before a low blood sugar -No pump settings or alerts can be entered -I need to delete this app because of the endless alerts
Mobile devices	-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
Server	-The inability to sync data with the server - Connect with the server
Insulin supply	-I need it to sync to my meters and pump -Needs ability to enter pump basal rates

	-no support for insulin pumps and basal rates
Doctors	-Email my readings to my doctor -The logs are in the format that doctors like to see
Forum	-Very supportive community -The people on here are so encouraging -Quickly connect and share with others who have this rotten disease -People there are really supportive and everybody really cares -Communicate with people that understand what it means to live with diabetes who faced the same problem

4.2. Axial coding results

From the 10 design concepts obtained from the open coding and using the procedures mentioned above (see sections 3.3 and 3.4), we created an ontology of three levels, shown in Figure 2. At the first level, we have the 10 concepts as design features of diabetes app. After that, we abstracted the design concepts into a higher level of 6 design principles and placed them at the second level of the ontology. We then grouped these design principles into three generic theoretical dimensions, *structural*, *technical* and *social*, and placed them at the third level of the ontology. As an example, the design principle, "*connection with supporting elements in user's context*", involves connecting the apps with the external supporting elements such as doctors and external tools such as servers, insulin pumps, and mobile devices. So, we generalized this principle as structural dimension [14, 35]. The design principles such as "*self-monitoring*", "*informative presentation*", "*effort expectancy*" and "*persuasive messages*" are related to apps primary functionality and usability. Therefore, they were grouped as technical dimension [8, 15, 16, 35]. Lastly, "*peers community support*" design principle was assigned as a social dimension as it is relates to social support [8, 15, 16, 35].

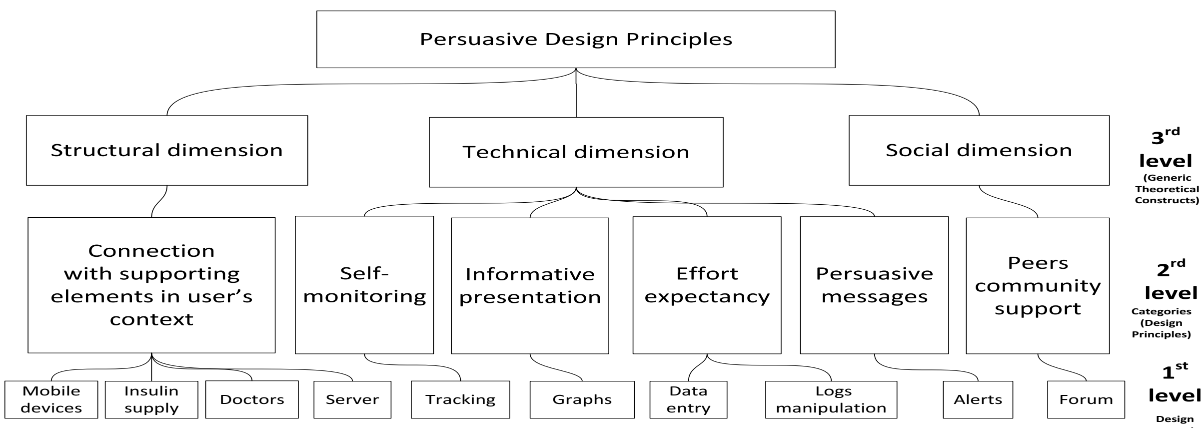

Figure 2: Domain ontology

4.3. Selective coding results

Based on the ontology, we developed "*technical*", "*structural*" and "*social*" design principles. Each set corresponds to the top-level dimensions in the ontology. Table 5 shows the *four technical design principles* we developed. These principles support the primary tasks of diabetes self-management, including *self-monitoring*, *informative presentation*, *effort expectancy*, and *persuasive messages*. Self-monitoring refers to providing means for users to track their performance or status [3]. Informative presentation means presenting users' data in a way that is readable as well as depicting users' improvements trends and historical patterns [33]. The concept of effort expectancy refers to the degree of ease associated with the use of the app [34]. Finally, the concept of persuasive messages refers to the app's effectiveness in reminding users of their target behavior [3].

Three of the technical principles intersect with the "primary task support" principles developed by Oinas-Kukkonen and Harjumaa [3]. First, *effort expectancy* corresponds to the reduction principle in [3]. Second, *persuasive messages* corresponds reminders principle in [3]. Third, [3] also includes the principle of *self-monitoring*. However, Grounding these principles in users' feedback helps provide empirical basis and further demonstrates the importance of them for persuasive systems. The other principle, "*Informative Presentation*", in this category is not found in [3].

Table 5. Technical design principles

Design Principle	Practical Examples
Self-Monitoring Apps should provide means for users to track their diabetes-related aspects. [3]	Track blood sugar, diet, exercise, meals, food, carbs, and medications.
Informative Presentation Apps should be able to provide users with readable and informative graphs, reports, and charts of their health-related data depicting their improvement patterns and historical trends. [33]	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.
Effort Expectancy Apps should reduce effort that users expend with regard to use, entering their health-related readings and data and update the existing ones. [34]	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 item is easy task.
Persuasive messages Apps should remind users of their target behavior during the use of the app. [3]	Having a remind feature for glucose, medications and meals.

Table 6 shows the structural design principle, which is related to the *connection with supporting elements in user's context*. This design principle is not found in [3].

Table 6. Structural design principle

Design Principle	Practical Examples
Connection with supporting elements in user's context Apps should help users to communicate their data with other supporting elements in their health environment such as insulin pump, clouds, and doctors	Enable users to synchronize their pump data (i.e. Basel and Bolus ratios) with the app. Support real-time synchronization of patients' data with a web server. Enable users to communicate their health-related data with their doctors

Table 7 shows the design principle in the social category. This principle, "*peers community support*", indicates that persuasive systems should support building peer-to-peer user communities that enable users to find those with similar health concerns and medical status to share both *emotional* and *informational* support. Emotional support refers to expressions of encouragement (e.g., "you can do it") that an individual obtains from communication with group members [36]. Informational support, on the other hand, means providing useful or needed information that assists in achieving one's goals [37]. Both emotional and informational support perceived from community members let users feel with a sense of belongingness and social identity [38], which can then persuade them to change their health behavior. To this end, it is useful for healthcare mobile apps to build functions such as a social forum that enables users to communicate with peers and to support integration with social media. This design principle is in line with the social support design principles developed in [3]. According to [3], 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.*

Table 7. Social design principle

Design Principle	Practical Examples
Peers community support Apps should help users to connect with their peers to share *emotional* and *informational* support.	Provide a social forum, which help all app users to meet together and share experience and emotion. Support integration with social media.

4.4. Evaluation

To evaluate grounded theory research results, two fundamental criteria should be assessed [7]. The first criterion relates to the rigor and validity of the qualitative data analysis and the second related to the extent to which the researcher has suggested theoretical generalization that is applicable to a range of situation [7]. With regard to the first criterion, we demonstrated the rigor of our content analysis approach in several ways. First, we adopted a text mining technique to extract the primitive concepts from large amounts of text data. Extracting knowledge from large amounts of data helps maintain a high degree of consistency and reliability, compared with manual coding with limited data [29]. Second, we provided multiple instances from the data which support the concepts produced (see Table 4).

With regard to the second criterion, namely the generalization of the research, we developed a theoretical framework by extracting knowledge from 30 different mobile applications. This framework demonstrated the importance of three important elements in these persuasive systems: *users structure aspects*, *technical aspects*, and *social aspects* in different applications. Other types of persuasive systems, aside from diabetes application will be examined in future research to explore the generalizability of the proposed framework.

5. Conclusion

This study aims to discover design principles of persuasive systems. We adopt a grounded theory based approach leveraging 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. We also compare our design principles with widely used existing design principles presented in [3].

Methodologically, this study leverages the capability of text mining within the grounded theory context. Instead of manually analyzing and coding the users' reviews, which is time-consuming and subjective, we used text mining, more specially, the LDA algorithm for topic modeling, to automatically extract concepts from large amounts of text data.

Practically, the findings of this study can help mobile app developers develop successful diabetes apps that promote user self-efficacy and sustainable use. 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 as secondary and complementary rather than integral to an application. This design approach does not capitalize on apps users' context and social behavior. The findings of the study highlight the importance of both the social and structural aspects beside the technical aspects in implementing the diabetes self-care apps. 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. Structurally, the designers of health smartphones should view the diabetes self-management app as a component within a holistic health system. In this system, the app should enable patients to communicate their readings and information with physicians, and it should be integrated with other health devices such as glucose meters.

Future research aims to explore the proposed method in other application domains and further explore the generalizability of the proposed principles for persuasive system design.

6. References

[1] H. Oinas-Kukkonen and M. Harjumaa, "Towards deeper understanding of persuasion in software and information systems," in *Advances in Computer-Human Interaction, 2008 First International Conference on*, 2008, pp. 200-205.

[2] H. Oinas-Kukkonen, "A foundation for the study of behavior change support systems," *Personal and ubiquitous computing,* vol. 17, pp. 1223-1235, 2013.

[3] H. Oinas-Kukkonen and M. Harjumaa, "Persuasive systems design: Key issues, process model, and system features," *Communications of the Association for Information Systems,* vol. 24, p. 28, 2009.

[4] S. M. Kelders, R. N. Kok, H. C. Ossebaard, and J. E. V. Gemert-Pijnen, "Persuasive System Design Does Matter: A Systematic Review of Adherence to Web-Based Interventions," *Journal of Medical Internet Research,* vol. 14, p. e152, 2012.

[5] M. Harjumaa and H. Oinas-Kukkonen, "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.

[6] B. G. Glaser and A. L. Strauss, *The discovery of grounded theory: strategies for qualitative research*. Chicago: Adline, 1967.

[7] M. D. Myers, *Qualitative Research in Business & Management*: SAGE Publications, 2009.

[8] G. Baxter and I. Sommerville, "Socio-technical systems: From design methods to systems engineering," *Interacting with Computers,* vol. 23, pp. 4-17, 2011.

[9] A. Jawdat, Q. Obeidat, and A. Aljanaby, "On the design of user experience based persuasive systems," *Computer and Information Science,* vol. 4, p. 90, 2011.

[10] C. K. Or and D. Tao, "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,* vol. 83, pp. 320-329, 2014.

[11] O. El-Gayar, P. Timsina, N. Nawar, and W. Eid, "Mobile applications for diabetes self-management: status and potential," *Journal of*

diabetes science and technology, vol. 7, pp. 247-262, 2013.
[12] D. Yoganathan and S. Kajanan, "What Drives Fitness Apps Usage? An Empirical Evaluation," in *Creating Value for All Through IT*, ed: Springer, 2014, pp. 179-196.
[13] V. Mclean. (2011, February 15). *Motivating Patients to Use Smartphone Health Apps*. Available: http://www.consumer-health.com/press/2008/NewsReleaseSmartPhoneApps.php
[14] M. Berg, C. Langenberg, I. vd Berg, and J. Kwakkernaat, "Considerations for sociotechnical design: experiences with an electronic patient record in a clinical context," *International journal of medical informatics,* vol. 52, pp. 243-251, 1998.
[15] E. Mumford, "The story of socio-technical design: reflections on its successes, failures and potential," *Information Systems Journal,* vol. 16, pp. 317-342, 2006.
[16] A. Cherns, "The Principles of Sociotechnical Design1," *Human relations,* vol. 29, pp. 783-792, 1976.
[17] C. W. Clegg, "Sociotechnical principles for system design," *Applied ergonomics,* vol. 31, pp. 463-477, 2000.
[18] K. Torning and H. Oinas-Kukkonen, "Persuasive system design: state of the art and future directions," in *Proceedings of the 4th international conference on persuasive technology*, 2009, p. 30.
[19] M. Kaptein, S. Duplinsky, and P. Markopoulos, "Means based adaptive persuasive systems," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011, pp. 335-344.
[20] T. Chomutare, L. Fernandez-Luque, E. Årsand, and G. Hartvigsen, "Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines," *Journal of medical Internet research,* vol. 13, 2011.
[21] S. Langrial, T. Lehto, H. Oinas-Kukkonen, M. Harjumaa, and P. Karppinen, "Native Mobile Applications For Personal Well-Being: A Persuasive Systems Design Evaluation," in *PACIS*, 2012, p. 93.
[22] D. Yoganathan and S. Kajanan, "Persuasive Technology for Smartphone Fitness Apps," in *PACIS*, 2013, p. 185.
[23] J.-Y. Mao, K. Vredenburg, P. W. Smith, and T. Carey, "The state of user-centered design practice," *Communications of the ACM,* vol. 48, pp. 105-109, 2005.
[24] C. K. Or and B.-T. Karsh, "A systematic review of patient acceptance of consumer health information technology," *Journal of the American Medical Informatics Association,* vol. 16, pp. 550-560, 2009.
[25] P. Akhavan and M. Jafari, "Critical issues for knowledge management implementation at a national level," *VINE,* vol. 36, pp. 52-66, 2006.
[26] N. R. Pandit, "The creation of theory: A recent application of the grounded theory method," *The qualitative report,* vol. 2, pp. 1-14, 1996.
[27] J. M. Corbin and A. Strauss, "Grounded theory research: Procedures, canons, and evaluative criteria," *Qualitative sociology,* vol. 13, pp. 3-21, 1990.
[28] R. Feldman and J. Sanger, *The text mining handbook: advanced approaches in analyzing unstructured data*: Cambridge University Press, 2007.
[29] C. H. Yu, A. Jannasch-Pennell, and S. DiGangi, "Compatibility between text mining and qualitative research in the perspectives of grounded theory, content analysis, and reliability," *The Qualitative Report,* vol. 16, pp. 730-744, 2011.
[30] F.-R. Lin, L.-S. Hsieh, and F.-T. Chuang, "Discovering genres of online discussion threads via text mining," *Computers & Education,* vol. 52, pp. 481-495, 2009.
[31] D. M. Blei, "Probabilistic topic models," *Communications of the ACM,* vol. 55, pp. 77-84, 2012.
[32] E. Haddi, X. Liu, and Y. Shi, "The role of text pre-processing in sentiment analysis," *Procedia Computer Science,* vol. 17, pp. 26-32, 2013.
[33] O. El-Gayar, P. Timsina, N. Nawar, and W. Eid, "A systematic review of IT for diabetes self-management: are we there yet?," *International journal of medical informatics,* vol. 82, pp. 637-652, 2013.
[34] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Quarterly,* vol. 27, pp. 425-478, 2003.
[35] O. El-Gayar, S. Sarnikar, and A. Wahbeh, "On the Design of IT-Enabled Self-Care Systems: A Socio-technical Perspective," in *System Sciences (HICSS), 2013 46th Hawaii International Conference on*, 2013, pp. 2484-2493.
[36] M. Mattson and J. G. Hall, "Linking Health Communication with Social Support," in *Health as Communication Nexus: A Service-Learning Approach*, ed Dubuque, IA: Kendall Hunt, 2011, pp. 181-218.
[37] C. Schaefer, J. C. Coyne, and R. S. Lazarus, "The health-related functions of social support," *Journal of behavioral medicine,* vol. 4, pp. 381-406, 1981.
[38] R. Brown, "Social identity theory: Past achievements, current problems and future challenges," *European Journal of Social Psychology,* vol. 30, pp. 745-778, 2000.