Abstract

Treatment non adherence is a growing concern for health care providers and policy makers. Mobile health (mhealth) has the potential to reduce treatment non adherence, cut the costs of providing healthcare, maintain and improve the quality of care. This research discusses the design of a mobile phone application to improve diabetic patients’ adherence to treatments. This research follows design science research guidelines and takes into account patients’ personal traits to develop personalized motivational messages. The application sends reminders and motivational messages to patients, tracks patients’ blood sugar level and generates reports. The application will be tested and evaluated by a group of diabetic patients on the effectiveness of promoting adherence, motivational messages and interface design.
Research Background

Treatments non adherence is a growing concern to clinicians, healthcare systems, and other stakeholders as it adversely impacts the quality of healthcare and patient safety, and increases the cost of care. Adherence has been defined as the “active, voluntary, and collaborative involvement of the patient in a mutually acceptable course of behavior to produce a therapeutic result” (Delamater 2006). Numerous studies have shown that patients with chronic conditions adhere only to 50% to 60% of medications as prescribed (Benner et al. 2002; Bosworth et al. 2011; Brian Haynes et al. 1996). In the United States, approximately 125,000 deaths per year are linked to medication non-compliance (McCarthy 1998), 33%-69% of medication related hospitalization are due to poor adherence (Osterberg et al. 2005). The total direct and indirect costs of poor medication adherence have been estimated to ranging from $100 to $300 billion per year (Berg et al. 1993). Moreover, medication non-adherence is likely to grow as the US population ages and more patients with chronic conditions (Ho et al. 2009).

With the advancing of mobile technology, mobile applications demonstrated great potential in providing new solutions to improve adherence to treatments. Mobile Health (mHealth) has the potential to cut the costs of providing healthcare, maintain and improve the quality of care. It will also play an important role in the healthcare industry's shift from pay for service to being rewarded for keeping people healthy and managing chronic diseases less expensively. Few researches has investigated the design of health mobile application and the effectiveness of using messages to motivate patients. This research discusses the design of a mobile application as well as the effectiveness of personalized messages.

Currently there are some commercial mobile applications designed for diabetic patients. However, there are several shortcomings in these applications: First, few applications are designed to improving adherence. Secondly, few applications focus on motivate patients. However, as suggested by literature, depression is one of the major reasons leads to non compliance with treatments (DiMatteo et al. 2000). Merely remind patients will not address the issue of intentional non compliance. Our research tries to fill this gap, and further, we investigate how to improve the efficiency of motivational messages by considering their personality types. Thirdly, the design of the applications has not considered the usability for elderly. In the united states, in the age group 65 years or older, 26.9% of people have diabetes (Boyle et al. 2010). Usability for elderly patients should be an important consideration in developing the applications.

We propose to address these problems by designing a mobile application that helps medication adherence taking into account medication taking, exercise and diet adherence. In our design process, we involve patients and physicians at all stages in the development of the application. We send motivational messages to motivate patients and promote continued compliance with medication, diet and exercise regimens. Based on psychological types theory (Jung et al. 1957), this research discusses how to effectively frame these messages. We also followed design guidelines to improve usability for elderly.

Our research develops a mobile application to investigate 1) the effectiveness of using mobile applications to improve adherence to treatments, and 2) the effectiveness of using motivational messages designed based on psychological types to promote adherence.

The paper is organized as following: first section presents relevant literature. Then the theoretical foundation is introduced. In the following section, we present research approach. Finally, the artifacts design and evaluation are discussed.

Related Work

Diabetic patients’ adherence to treatments

This research chooses to focus on diabetic patients for several reasons. First, the prevalence and incidence of diabetes mellitus have been increasing substantially in the United States as a result of multiple factors including increasing obesity, aging, and demographic changes. According to Centers for Disease Control and Prevention (CDC), in 2010, nearly 26 million people, or 8.3% of the US population, were affected by diabetes (FIDIS 2013). Total prevalence of diabetes is projected to increase to 21% to 33% of the US adult population by 2050 (Boyle et al, 2010). Second, diabetes is a chronic disease with
serious complications. Medical expenses for people with diabetes are 2.3 times higher than for people without diabetes. The total estimated diabetes cost in the United States in 2007 was $174 billion. That is, 1 in 5 dollars spent on health care nationwide (American Diabetes Association, 2008).

Non adherence to treatments is common within patients with diabetes because self health management for these patients is a tough job. Patients need to adapt to healthy eating habits, keep physically active, take medications as prescribed, and monitor blood sugar level regularly. These tasks are part of their daily lives. Non-adherence for diabetic patients also stems from the fact that the adverse impacts are not immediately felt by patients, with many complications developing over years. However, many of these complications developed as a result of not properly controlling blood sugar levels are sever.

**Factors Impact Medication Adherence**

Factors impacting non-adherence can be broadly categorized into three groups (a) Patients beliefs about the effectiveness, side effects, and necessity of the treatments (Horne et al. 2005), (b) logistics and habits, such as complexity of regimens, access to healthy food, and exercise habits ((Claxton et al. 2001), (c) motivational or psychological factors and social support (DiMatteo 2004; DiMatteo et al. 2000). A literature review on the factors contributing to non compliance is attached in table 1.

**Interventions to Medication Non-adherence**

Prior literature show that in general, to improve medication adherence unimodal interventions have been less successful than multimodal interventions, because the reasons for non-adherence are often multifactorial (Haynes et al. 2008; Heneghan et al. 2006; Kripalani et al. 2007; McDonald et al. 2002; Schroeder et al. 2004). Interventions that have demonstrated some success include those that reduced the number of daily doses of medications, used motivational strategies, packaged medications into special containers (eg, pill boxes or blister packs), provided more convenient care, educated patients, or involved monitoring and feedback (Ho et al. 2009). A brief review of the interventions to medication adherence is presented in table 2. Less study has investigated ways to improve exercise and diet adherence.
### Table 1. Factors contributing to non compliance

<table>
<thead>
<tr>
<th>Factor</th>
<th>Citation</th>
<th>Finding</th>
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<tbody>
<tr>
<td>Does frequency, medication regimen</td>
<td>(Eisen et al. 1990)</td>
<td>Compliance improves dramatically as prescribed dose frequency decreases.</td>
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<td></td>
<td>(Claxton et al. 2001)</td>
<td>The prescribed number of doses per day is inversely related to compliance. Simpler, less frequent dosing regimens resulted in better compliance across a variety of therapeutic classes.</td>
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<tr>
<td></td>
<td>(Paes et al. 1997)</td>
<td>The reduction of dose frequency may decrease total noncompliance, but at the same time, it increases the risk of overconsumption.</td>
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<tr>
<td>Health literacy, patient education and demographic factors</td>
<td>(Seltzer et al. 1980)</td>
<td>Results show that &quot;educated&quot; patients tended to be more compliant on outpatient follow-up and were less fearful of side effects and addiction.</td>
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<tr>
<td></td>
<td>(Beardon et al. 1993)</td>
<td>Non-compliance varies with age, sex, general practitioner, exemption status, and with day of the week the prescription was written.</td>
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<tr>
<td></td>
<td>(Ren et al. 2002)</td>
<td>Patients who were younger and less active in their treatment decisions tended to be less compliant with antihypertensive medications.</td>
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<tr>
<td>Patient Belief-effectiveness; side effects; necessity</td>
<td>(Horne et al. 2005)</td>
<td>Decays of research show that patient beliefs are important predictors of medication adherence.</td>
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<tr>
<td>Psychological issues and social support</td>
<td>(DiMatteo et al. 2000)</td>
<td>Compared with non depressed patients, the odds are 3 times greater that depressed patients will be noncompliant with medical treatment recommendations.</td>
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<tr>
<td></td>
<td>(DiMatteo 2004)</td>
<td>Adherence is 1.74 times higher in patients from cohesive families and 1.53 times lower in patients from families in conflict. Marital status and living with another person (for adults) increase adherence modestly.</td>
</tr>
</tbody>
</table>

### Table 2. Interventions for medication adherence


Interventions and results

<table>
<thead>
<tr>
<th>Citation</th>
<th>Interventions</th>
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<tbody>
<tr>
<td>(Vervloet et al. 2012)</td>
<td>A comprehensive literature search was conducted in PubMed, Embase, PsycINFO,</td>
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<td></td>
<td>CINAHL and Cochrane Central Register of Controlled Trials. This review</td>
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<td></td>
<td>provides evidence for the short term effectiveness of electronic reminders,</td>
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<tr>
<td></td>
<td>especially SMS reminders. However, long term effects remain unclear.</td>
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<td>(Murray et al. 2007)</td>
<td>Randomized clinically stable outpatients with a diagnosis of heart failure to</td>
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<td>an intensive pharmacist-led intervention versus usual care and found a 10.9%</td>
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<td>improvement in adherence to cardiovascular medications. The intervention</td>
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<td>patients also had fewer emergency department visits and hospital admissions,</td>
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<td>as well as lower healthcare costs.</td>
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<td>(Lee et al. 2006)</td>
<td>Randomized patients to an intervention composed of patient education,</td>
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<td></td>
<td>medication reminder packaging, and frequent clinic visits (every 2 months)</td>
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<tr>
<td></td>
<td>versus usual care and showed improvements in medication adherence (≈30%) and</td>
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<td>systolic blood pressure but not LDL cholesterol.</td>
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<td>(Piette 2000; Piette et al. 2001)</td>
<td>Randomized veterans with diabetes mellitus to an intervention that consisted</td>
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<td>of telemetry with interactive voice response technology and weekly nurse</td>
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<td></td>
<td>feedback and demonstrated improvements in medication adherence and diabetes-</td>
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<tr>
<td></td>
<td>related symptoms, as well as a trend for improvement in hemoglobin A1C.</td>
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<tr>
<td>(Fulmer et al. 1999)</td>
<td>Telephone interventions are effective in enhancing medication compliance and</td>
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<td></td>
<td>may prove more cost effective than clinic visits or preparation of pre-poured</td>
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<td></td>
<td>pill boxes in the home.</td>
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<tr>
<td>(Roter et al. 1998)</td>
<td>No single strategy or programmatic focus showed any clear advantage compared</td>
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<tr>
<td></td>
<td>with another. Comprehensive interventions combining cognitive, behavioral, and</td>
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<td>affective components were more effective than single-focus interventions.</td>
</tr>
</tbody>
</table>

Table 2. Interventions for medication adherence

**Design Mobile Applications for Elderly**

Mobile health applications have the potential to improve the quality of life and facilitate independent living of elderly. With the increasing aging population, more applications considering the usability for elderly should be developed. Holzinger et al pointed out that mobile applications for elderly should achieve these goals in design 1) adapted to the end user’s physical impairments, 2) the interface must offer a relative degree of familiarity to overcome any reservations felt by the end user, and 3) The benefit of using the device must be appreciable to overcome the reluctant of learning new technologies (Holzinger et al. 2007). Research suggests that older users had a lower navigation performance than younger users, however their performance matched younger users’ when using mobiles with low complexity (Ziefle et al. 2005). Wilkowska and Ziefle investigated the acceptance of personal PDA by elderly and found that acceptance is mainly influenced by the individuals’ learning history with technology. Though, the tutorial training significantly affected acceptance (Wilkowska et al. 2009).

**Theoretical Foundation**

**Theory of Psychological Types**

The essence of the psychological theory described by C. G. Jung (Jung et al. 1957) is that much seemingly random variation in the behavior is actually quite orderly and consistent, being due to basic differences in the ways individuals prefer to use their perception and judgment. Prior research has examined in considerable detail the relationship between personality type, information processing, and decision making. One of the most adapted psychological type measurement instrument is the Myers–Briggs Type Indicator (MBTI) (Myers et al. 1988). Much research in the area of marketing, strategy and human resources have used MBTI to understand personality type in order to improve communication effectiveness and message persuasiveness (Edwards 2003; Gardner et al. 1996; Jennings et al. 2006). The purpose of the Myers-Briggs Type Indicator (MBTI) personality inventory is to make the theory of psychological types understandable and useful. MBTI assesses personality types by considering an
individual's preferences on four pairs of psychological types: the Extraversion-Introversion (E, I) explain different attitudes people use to direct their energy and the perceptual orientation of the individual. Sensing and Intuition (S, N) refer to two ways of gathering information and understanding situations. People with a sensing preference rely on things that can be perceived and are considered to be oriented toward real things. Thinking and Feeling (T, F) are two ways in which to organize and structure information and come to a conclusion. A preference for thinking indicates the use of logic and rational processes to make deductions and decide upon action. Finally, Judging-Perceiving (J, P) describes how you like to live your outer life. The judgment-perception preferences were invented by Briggs and Myers to indicate whether rational or irrational judgments that is dominant when a person is interacting with the environment. In our research, we focus on thinking- feeling preference because our research focuses on understanding how motivational messages can influence people's decision making process. Thinking implies a preference for applying analytical and logical principles to make objective decisions, following clear and consistent principles. While those people who prefer Feeling may prefer to make decisions by reference to their own and other's values, put more weight on personal concerns and the people involved. Adapting the theory, sending motivational messages based on patients' psychological type should improve the effectiveness of the message. For thinking type, messages should be more logical and state facts, while for feeling type, the messages should be more personal.

Research Approach

Research Process

This research follows a design science research approach proposed by Peffers et al (2007). The process is as following:

- **Problem identification and motivation**: treatment non compliance is a common issue among diabetic patients; there is no evaluation of the effectiveness of current applications in terms of improving adherence; current mobile applications do not personalize messages based on psychometrics evaluation of personality types; current applications do not consider the usability for elderly.
- **Objectives of a solution**: design a mobile application to effectively motivate patients and improve adherence; improve the usability for elderly.
- **Design and Development**: the design of the application is based on patients' input collected through focus groups, literature review and product review; motivational messages are designed based on patients' psychological types; guidelines for developing applications for elderly are followed.
- **Demonstration**: technical review of the prototype; test the messages based on patients' psychological types.
- **Evaluation**: the effectiveness of messages designed based on psychological type theory; the effectiveness of the application to improve adherence and; usability for elderly patients.
- **Communication**: This research will generate conference and journal publications.

The process of the research is presented in figure 1. The research is currently in the stage of feedback and evaluations.

![Figure 1. Research process](image-url)
Artifacts Development

Functionality Design

In order to better design the artifacts, three focus groups, 2 interviews with physicians, and 2 interviews with diabetic educators. The purpose of the focus group and interviews was to understand the factors that impact adherence to prescribed medication, diet and exercise regimens as well as to elicit requirements of features in the application.

The physicians interviewed are primary care physicians who treat diabetes patients. The diabetes educators are certified by American Diabetes Association.

Each focus group included 6 diabetic patients, 1 diabetes educator, 1 researcher and 1 note taker. These patients are recruited through patient community groups (“diabetes sisters” and “patients' voice”) from the Buffalo area and have diverse backgrounds in terms of education level, ethnicity, age and gender. In these three focus groups, 5 patients were under the age of 40, 8 patients were between the age of 40 and 65, and 5 patients were over 65 years old. Each focus group lasted about 40 minutes.

We designed the functions of the application based on the input from the focus groups, literature review, existing applications product review, and the input from diabetes educators and physicians.

The answers of the focus groups were recorded by both the note-taker and the researcher. The notes from different person were then compared and coded using open coding scheme (Crook et al. 1998). Main themes for each answer were identified and the script for the focus groups and the main themes identified are as following:

- **What are the difficulties you are facing with taking medications as described?**
  The constancy – you can never take a vacation from diabetes; take medication at the same time every day; bring medications the day before if you are going to be out late the next day; side effects, such as feeling extremely tired; fear of low blood sugar.

- **What are the difficulties you are facing with adapt to healthy eating?**
  Food preference and habit; make food for one person different from everyone else in the family; snacks in the house; few food options when eat out; healthy food cost more.

- **What are the difficulties you are facing with achieve your exercise goals?**
  Sit all day at work and doing exercises takes extra effort; do not know how much calories burned; physical challenges; bad weather; hard to persist; lack of motivation.

- **Do you experience negative emotions because of diabetes?**
  Almost everyone agree they experience negative emotions from time to time. These emotions include: panic; feel loss of control; overwhelmed; angry; frustrated when doing everything right but still have high blood sugar level; frustrated after years of dealing with diabetes (the longest participant has lived with diabetes for over 30 years).

- **Have you used any mobile or web applications for diabetes management? Have you used online diabetes support groups?**
  Most of the participants have used online forums to search for information, half of the participants have used mobile apps (not necessarily specific for diabetes) to track calorie intake, calorie burn in exercise and blood sugar reading.

- **What functions would you like to see in the applications?**
  Functions related to medication taking: travel and medication check list; reminders. Functions related to exercise: exercise calories calculate; exercise videos; search for other patients to do exercise together; reminders. Functions related to diet: recommend recipe and generate shopping list; recipes based on season and time takes to prepare; food calorie calculate.
Functions related to blood sugar tracking: blood sugar record and generate reports; upload to the cloud.
Motivation and social support: Send messages to friends; search for community events such as dancing, walk, etc; daily inspirational messages; family member education and support.

Finally, we decided on the main functions of the application: reminders for medication taking, medication check list; blood sugar tracking and reporting; daily motivational messages; recipes and exercise programs recommendations.

**Message Design**
In order to test whether motivational messages based on the psychological type are more effective, we first selected 60 motivational messages from diabetes forums and magazines, 30 of them are logical and 30 of them are personal. As part of the focus groups, we randomly presented 10 messages to each participant and asked them to rank whether the message is personal, logical, both or neither. Each message is evaluated by three patients. If the message is ranked the same by all three participants, we kept the message for use in the application. Thus, we eliminated messages that are vague in message type. We also modified the messages based on patients’ suggestion (such as word choice, length, etc.), finally, 50 messages (25 messages in each type) are kept for the application.

**Design for Elderly**
Prior research has suggested that User-Centered Development (UCD) is very effective when developing applications for elderly (Holzinger et al. 2007). Some principles of UCD include: understand the end user and their tasks; setting measurable goals and involve end users from the very beginning. Based on UCD, we presented the prototype to elderly users to get their feedback and revised our design many times until they felt the application was easy to learn and use. Specifically, we implement the following features:

1) Features to overcome physical impairments: clear color contrast, larger fonts and icons, avoid keyboard entering whenever possible, larger targets for touch screen objects, voice input options.

2) Features to reduce complexity: straightforward layout, less content in one screen, simple navigating, avoid technical terms, include video instruction in the application.

**Application Development**
Based on the functionality and interface design, the mobile application was developed. The development followed the standard software development life cycle (SDLC) methodology and took four months to complete. The mobile application is developed in Java for the android system. A screen shot of the application is presented in figure 2.
Artifacts Evaluation

This research is now in the stage of evaluation. We will use the following methods to evaluate different aspects of the artifacts:

Subject matter expert evaluation

Physicians, nurses, communication experts and patient committee member will review the application and messages and provide feedback on the quality of the design and content. Their feedback will be used to refine the product further.

Effectiveness of mobile application to promoting Adherence

The application will be installed in 30 diabetic patients' phone. These patients will use the application for two weeks and fill out a survey to indicate the effectiveness of the application in terms of promoting adherence.

Effectiveness of motivational messages based on psychological types

30 diabetic patients will be asked to fill out a short survey adopted from MBTI to determine their personality types. Then each patient will be presented with 10 groups of messages, with one personal message and one logical message in each group. Patients will rank which message is more effective in terms of promoting adherence. Chi square test will be used to validate the association between psychological type and message preference.

Elderly usability

Based on Seffah and Metzker’s matrix for software usability measurement and (Seffah et al. 2004) and Holzinger et al’s matrix for measuring usability of mobile applications for elderly (Holzinger et al. 2008), we proposed a 4 item measurement for evaluating the usability. These items are – likeability, controllability, understandability, trustworthiness. 30 elderly patients will use the application and fill out a survey to evaluate the usability of the application.

Conclusions and Discussions

In this paper, we developed a mobile application to help diabetic patients adhere to treatments. Our research contributes to theory and practice by 1) investigates the effectiveness of using mobile applications to improve adherence 2) by adapting psychological type theory we tested the effectiveness of motivational messages based on personality type. There are some limitations can be addressed by future research: first, future research can investigate more ways to personalize the application to better improve adherence. Second, better measurements for adherence (including longitudinal adherence) should be developed). Third, to improve the usability of the application, such as ways to connect it with existing blood sugar reading equipments can be developed. We hope that our efforts will help to make a difference in the lives of the patients.

Reference


