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mCAT: Development of a Generic mHealth Tool for Continuous Assessment, Automatic Intervention, and Analysis

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MCAT: DEVELOPMENT OF A GENERIC MHEALTH TOOL
FOR CONTINUOUS ASSESSMENT, AUTOMATIC INTERVENTION, AND ANALYSIS

by

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ABSTRACT
MCAT: DEVELOPMENT OF A GENERIC MHEALTH TOOL
FOR CONTINUOUS ASSESSMENT, AUTOMATIC INTERVENTION, AND ANALYSIS

A B M Kowser Patwary

Marquette University, 2016

Use of mobile health (mHealth) technology for behavioral and psychological studies through continuous assessment and intervention is found to be effective. Also, the use of smartphone has increased rapidly last few years, as well as its uses for health support. mHealth research is applied for smoking cessation, motivating cancer survivors and mentoring peers for social engagement. While in most settings researchers are developing their own intervention and assessment tool for each different research. In this study mHealth research is applied and generalized across a range of applications, including smoking cessation, motivating cancer survivors and mentoring peers to improve social engagement. Here at Ubicomp Lab, Marquette University we have developed similar tool Mobile peer-mentoring: An approach to making veterans seek mental health care support a normality, and Walking Forward for Physical Activity: The mHealth Tool for Motivating Cancer Survivors. This study analyzed these research, and proposed a design and implemented it as a generic mHealth tool, named mCAT (Mobile Continuous Assessment Tool). We also have shown the complexity to design challenges to develop an effective smartphone application that meets user expectation. The goal of this generic mHealth tool is to help future research designed for continuous assessment and intervention. This tool provides the initial building block as modules, customizable features, and API to start with the actual implementation. mCAT expects to be cost effective, easily customizable, leverage learning curve on the open standard.

ACKNOWLEDGMENTS

A B M Kowser Patwary

DEDICATION

I would like to dedicate this work to health researchers who are improving our quality of life with their discoveries.

Thank You

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CHAPTER 1

INTRODUCTION

Smartphones are the powerful computational device which can offer cost effective service. Smartphones are part of our daily life and its adoption is increasing day by day. According to Pew Research Center, "64% of American adults now own a smartphone, up from 35% in 2011." [31]. Because of its well adoption and portability, the smartphone is a good candidate for providing health care support.

1.1   Mobile Technology

Mobile technologies are getting powerful and more to offer rather than just communication. Moor's law predicted growth of semiconductor density for the computing device. Rapid improvement of semiconductor technology benefited mobile technology two-way. First, improvement of mobile processor allowed powerful smartphone as a computing device. Second, users now own affordable powerful computing device. Low earnage people enjoy the most benefit from these affordable smartphone. These users can connect to The Internet and get help faster via smartphone applications.

At the same time, there is a good progress with smartphone operating system like Android, iOS. This development made it easier to develop native smartphone application. This new development helped end users to connect to the Internet and getting help much easier. Users are now using the smartphone to access services like health information, banking, government services, and etc. According to Pew Research Center [31], "62% of smartphone owners have used their phone in the past year to look up information about a health condition".

As it appears it is a strong reason to research on mobile technology for health care support. As we can see, smartphone are getting part of daily life for its computing power and usability.

1.2   mHealth Research - The Problem of "Buy or Build"

Studies found mHealth research is effective. Smartphones can be a cost effective solution too. A smartphone is the new powerful tool to reach people for health care support. Simple smartphone applications for the knowledge base, daily health journal are helpful for users.

Researcher from health sciences, human-computer interactions (HCI), and other related fields are studying on Mobile Health (mHealth) technology. Predrag Klasnja et al. [18] summarized ongoing researches on mHealth. They are trying to discover new approaches to using the smartphone for health care. They identified key requirements for intervention, outlined future mHealth research direction in this area. Google Fit for android and Apple Health Kit for iOS are a good example for such smartphone applications. Free heart rate monitoring applications are available [12] on Google Play Store.

1.3   mHealth for Behavioral and Clinical Psychology Studies

One of the main research areas of health science is behavioral and clinical psychology. These studies uses experimental approach to change behavior of participants and collect their behavioral data. Researchers motivate and train these participants to change their behavior to restrain from unwanted activities. Researchers continuously monitor those participants to understand their behavioral change if any. Participants works with researchers, trainer and caregiver for these training. This is a continuous process of training, assessment, analysis.

Luxton et al. [19] have done extensive research for mHealth tool. They have discussed capabilities of smartphone for mHealth research. They have given overview on use of smartphone for clinical practice, real time communication between user and caregiver, privacy and security issues. They found smartphone can leverage responsibility of trainer to smartphone application. They studied about privacy and security for these mHealth tool. It is a critical situation for a lost phone.

Studies have found behavioral and psychological studies with mobile technology is an effective approach. [14, 8, 21]. These studies use mobile technology to continuously monitor human subject. Also, guide them with the motivational text throughout the study. And, finally, compare its effect with the baseline study. It involves collecting subject's instantaneous data at any random time [30] or any scheduled time.

We studied these mHealth research and discussed our findings. We found these intervention and data collection process to be unique for each research. Thus, usually, researchers ended up developing a different tool for each specific study a costly endeavor. A more optimal solution would be a single tool with deep customization capabilities allowing mental health specialists and researchers to deploy sophisticated, highly tailored mobile mental health systems from a single base system.

1.4   Design and Development of mHealth Application

In this literature, we discuss adoption of smartphones by users. Also, we discuss current ongoing health studies focused on using mobile technology. We have identified key requirements for mHealth tools developed for behavioral & clinical psychology studies. Also, we investigate workflow for these mHealth tools. We propose the results of this analysis as a set of requirements for a generic mHealth tool. We have discussed these findings in more detail in this literature. Later we discuss the mHealth tool we have developed from these proposed requirements. The purpose of this mHealth tool is to help future mHealth researchers. This tool helps with rapid development and deployment of new mHealth tools. This tool will simplify implementation of new mHealth tool for behavioral and clinical psychology. We have analyzed these proposed requirements. This analysis leads to the development of the new generic mHealth tool, mCAT. (Mobile Continuous Assessment Tool).

We discuss what are the key consideration to develop the mCAT tool. We have studied existing research and tools developed for intervention and continuous analysis. Systematic analysis of requirements is needed to be done to design and develop a working software. We use Software Development Life Cycle (SDLC) for this systematic analysis. We discuss in detail about challenges we have faced. These challanges are user interface design, user enrollment, password recovery and user intervention

Later we discuss how the developed system applies to existing research. mCAT have the possibility to be used for other researchers e.g. mHealth support in rural areas. Also, we discuss its limitation to be a robust mobile application. Also, given its limitation, we discuss how we can improve it for future.

CHAPTER 2

BACKGROUND AND MOTIVATION

As we have discussed, mobile technology is the promising tool for delivering health care support. One of the key areas is behavioral and clinical psychology where researcher are using tools. In this chapter, we discuss key issues for these mHealth tools.

2.1   User Interface Design

One aspect of designing user-friendly application is to offer good user interface. It is challenging to accommodate a concept in a small area. Designing of User Interface for smartphone applications requires careful consideration. Continuous research on Human Computer Interaction for small devices is going on. HCI for smartphone application helped to address this UI design challenges. Researching on usability and expressiveness of the smartphone application provides better user-friendly experience. Google researched on user interface created the "Google Material Design" standard. This standard specifies to UI components and answers two questions:

- How to design a component
- When to use these components

A smartphone application may run on devices with different screen sizes. Thus, user interface design for smartphone applications needs to consider this issue too. Google Material Design [11] provides a guideline for responsive User Interface too. The guidelines recommend how to accommodate UI components for different screen size. There is a different implementation for Google Material Design. Microsoft's research on User Interface came out as "Microsoft Tiles". It also specifies User Interface design guidelines including the responsive user interface.

A good user interface can close the gap between a user and the help the user is looking for. Especially user engagement is important for research on mHealth for motivating behavioral change. So we believe it is a key rule to design a user-friendly application.

2.1.1   Designing a Generic UI Component

In contrary, it is a challenge to design a generic UI component. A generic UI component needs to accommodate the minimum standard. It needs to support multiple screen size, offer the flexible framework for customization. We have discussed the multiple screen size issue. As a

generic component, it needs to show UI hints depending on underline data and the user interaction. This scenario varies depending on the requirement.

As an example, the iPeer study provides veterans summary in the Mentor Application, shown in the Figure 3.5.8. It is a candidate for generic UI component. A mentor, caregiver or researcher expects summary for their participants. This summary UI should provide hints on users current status and progress during the study. As of now, the veteran summary UI provides a graph. It indicates veterans latest survey submission status. Designing of this UI component went through an iterative process. Finally, we were able to achieve a new UI that offers the mentor a general overview of his peer. We worked with veteran peers, mentor and researchers to identify their expectation from this UI which leads to design and development of this UI.

2.2   Users Privacy and Security

The human studies need to maintain Health Insurance Portability and Accountability Act (HIPAA) compliance [22] for subject's privacy and data security. It is another important concern while researching with human subjects. HIPAA privacy rule protects patients personal information. It specifies on how and what information researchers can distribute without patient's authorization. The security rule specifies how to store and protect this information with required security measure.

As we are getting connected, it increases threats to privacy and security. When we talk about privacy it means user's personal information that can identify a user. As an example, user's social security number can uniquely identify a user. A research participant may or may not choose to disclose their personal information. Also, participant's health data is private for that user. Researchers have to maintain security standard must protect user's privacy. HIPAA is applicable for any human subject research. When developing mHealth application it needs to follow the HIPAA privacy and security standard.

Protecting data collected from research participant is another concern. The research will have users' privacy, health and survey data collected throughout the study. Again security measure needs to be taken to secure these data throughout the study and after the end of a study. There are different ways data security is breached. Also, there are safeguards to address these threats. A generic mHealth tool should make sure that these standard safeguards are in place.

2.3   Mobile Security and User Experience

Additionally having Privacy and Security with the ease of user interaction is important. Often designing application with minimum privacy and security standard can lead to poor user experience. Botha et al. [1] have studied this issue in detail. They have shown mobile is not capable of offering similar user experience with security compared to the desktop application. Even though an application meets the user experience it lacks the privacy.

We have developed a novel mHealth application, iPeer, which models the peer mentor concept. One of the key requirement for this application is allowing a peer to register into the system without any personal information. It raises few issues. Since there is no personal information, e.g. personal email address or phone number. There is no identifier between the profile stored in the system and participating peer. It creates a poor user experience for enrolling these user group into the system. It makes the user registration complicated, also complicates the password recovery workflow. We have introduced a new workflow having a mentor as the mediator, who start this processes. This process is different from in general user registration and password recovery process. We have elaborated this issue later in this literature.

mHealth research is an open field to incorporate privacy and security offering better user experience. Researchers need to make sure that these HIPAA privacy and security measures are taken into consideration when developing this application for human studies. So this study incorporates these design challenges implemented an approach to solving this.

2.4   Intervention

Intervention is the key component for behavioral studies. Sending a text message is the most common way to intervene. Participants receive an intervention. Intervention helps to improve or change health behavior positively or refrain from risky behavior. Text message based intervention is applied for smoking cessation [24], diabetics education [32]. Researchers developed the new system for these studies.

The developed system sends motivational and reminder texts to a participant. The system can predetermine and/or depend on subject's response. As an example, weight loss program sends following text message if the participant abstein from physical activity for substantial period.

"Accept the challenges so that you can feel the exhilaration of victory - George S. Patton"

A participant may receive these interventions at any random time or specified time of the day depending on the study. Sometimes participant may choose their own intervention schedule too. Again intervention rule can vary depending on the study designed.

2.5 Continuous Assessment

Initially, researchers collect baseline data from a subject. They continuously assess human subjects throughout the study. Also, mobile devices send sensor data as a survey. All these continuous assessments work as a marker. These data collection can be instantaneous, short lived. Participants have to submit these survey within a limited period of time upon receiving a notification. Also, these survey can be open for completion at any time during the study.

Consolvo et al. [5] have used the mobile sensor to collect physical activity, Rizwana Rizia et al. [27] have collected survey data from the participant. Now these continuous assessment is unique for each of these research.

2.6 Survey

Data collection is an integral part of any research. Generally, a survey has a common set of questions. We tried to address key problems like survey creation, and data collection. We tried to build a model that can help researchers to create a survey. Right now the system offers survey question with multiple choice. It utilizes Entity Attribute Value (EAV) model to create survey questions and answers.

Survey creation is a complex procedure. Question or question set can be dependent on the previous answer. Answer choices can vary too. Having an EAV model can help question type creation easy for future expansion.

2.7 User Enrollment

Another aspect of the study is the enrollment of user into the system. Both mentor and participant enroll into the system. Data collected from participant identifies a user. There are be scenarios where a participant has to submit data as an anonymous user. The purpose of this anonymization is to protect their privacy. and create new challenges, which we discuss later. The

system should be able to separate users personal information from the data collected by the survey or mobile sensor.

mHealth studies for behavioral studies solved these problems separately. As of now there is no such mHealth tool, which focuses on intervention and continuous monitoring, privacy and security as a standardized option [4]. This mHealth tool should provide common features focused on continuous monitoring, intervention with motivational text and reminder, analysis of data, extend-able with Application Programming Interface and finally easy to deploy. It is not that any one of these component is novel, but when they are put together and abstracted so they they can be dynamically configured and customized for an mHealth application, this is a fundamentally new approach.

CHAPTER 3

RELATED WORKS

Active research has been going on in behavioral and clinical psychology using mHealth. mHealth helps these researchers for continuous assessment of the human subject. Given the scope most of these research, it provides positive outcomes. These researchers explored around the implementation of smartphone application focusing on each research problem. The result of these researches shows a good sign of the positive outcome.

3.1   SmartCAT - mHealth Platform for Child Anxiety Treatment

Pramana Gede et al [25] developed the SmartCAT mobile application. This is a smartphone application to overcome child anxiety. A youth uses this tool and it provides cues according to their CBT training session. Therapists watch these participants with the help of a web portal. The study found the application to be helpful. Also, it found to be easy for both participants and therapist.

3.2   e-ESAS - Mobile Based Breast Cancer Symptom Monitoring Tool

Md Haque et al. [13] have shown how motivation and intervention can help breast cancer patient with the use of mobile technology. The e-ESAS mHealth tool developed by the team is successful integrating "motivation" and "automation". According to the study, the automated alert generation and continuous monitoring from breast cancer patient improved better communication among doctor, nurse and patient creating the motivation-persuasion-motivation cycle.

3.3   Behavior Change from Alcohol Use and Weight Loss

Amy M. Cohn et al. [3] compared effectiveness of existing mobile technology targeting improvement of alcohol uses behavior utilizing the momentary assessment. These applications promised to improve self-control with momentary assessment among alcoholics. Though there are few successful use cases, the study identified more research needs to be done to address this issue. Kevin Patrick [23] et al. found that the text message based intervention is helpful for weight loss. According to the study, At the end of 4 months, the intervention group (n = 33) lost more weight than the comparison group (1.97 kg difference, 95% CI 0.34 to 3.60 kg, P = .02) after

adjusting for sex and age.

3.4   mHealth for Smoking Cessation

Jami et al. [24] researched on smoking cessation by using intervention and motivational text message. According to the study, "At 6-week follow-up, 43% had made at least one 24-hour attempt to quit, and 22% were quit based on a 7-day prevalence criterion. The findings provide support for using wireless text messages to deliver potentially effective smoking-cessation behavioral interventions to college students." This study has designed a full application with the similar workflow. Study have developed the website for user registration, the web portal to provide feedback in on-line. Researchers sent text messages as a form of intervention. Its frequency increases as the subject reaches close to smoking quit day. On the final day, depending on the participant's earlier feedback, the system sends the motivational or instructional text. This system is a good example of intervention depending on the user feedback.

3.5   iPeer

At Ubicomp Lab, Marquette University we have developed a novel mobile based peer-mentor system. We collaborated with Dryhootch of America, Medical College of Wisconsin. Dryhootch runs a peer-mentor program to help combat veterans for civilian reintegration. This mobile based mHealth system augments the peer-mentor program run by Dryhootch.

3.5.1   Civil Reintegration for Combat Veteran

Veteran struggling with civil reintegration often shows PTSD symptom. They experience attention disorder, nightmare, self-destructive behavior, alcohol abuse, and etc. U.S. Department of Veteran Affairs conducted a study among Vietnam War veterans. They published their findings as "National Vietnam Veterans' Readjustment Study" [26]. Analysis of this findings says, "According to the results gathered using these assessment tools, an estimated 15.2% of male and 8.5% of female Vietnam Veterans met criteria for current PTSD" [17].

3.5.2   Peer-Mentor Modeling

It is not easy for combat veterans to return home and adapt to civil life after spending years at war. This is not something a veteran can experience every day of life. Rizia et al. have discussed this in detail in the Mobile Peer-Mentoring [28] research. It shows an approach to

solving this problem using mobile technology. Dryhootch [7], a community organization led by combat veterans, runs a set of program for welfare of combat veteran. One of the programs is peer mentor support especially for combat veterans returning home.

A combat veteran faces difficulties for social reintegration. At Dryhootch veteran mentor works with his veteran peer. The mentor went through the same difficult period as the peer does for social reintegration when returns to home from war. The mentor guides his peer and shows the right way to address these challenges. At the same time, mentors collect survey data from these veteran using paper. A veteran peer can submit data using smartphone application. This technology can make this process efficient and cheap. It gives the veteran opportunity to work with more peer at the same time.

A mentor can keep in touch with veteran using smartphone application. The motivation is, the veteran peer submits surveys using smartphone application. The veteran mentor gets updates about peers' survey data using the smartphone application. They can compare their peers' previous survey submission history. Then the mentor can decide who is doing better or need consultation.

3.5.3   Trust Issue

One of the issue with collecting data using mobile technology from the veteran is the trust issue. We have identified these trust issue. These issues are related to collecting data from veterans and saving it online. Veterans do not feel safe to share their personal data. They are afraid of the government. They think that government may know their weakness and use that weakness against them to cut their social benefits. Also, some of these veterans trust on the government conspiracy. Rizwana et al. [28, 27] have discussed these issues in more detail.

3.5.4   Design Challenge

It is challenging to design a data collection system where users do not trust the system. We addressed this challenge two-way. First, the study involved veteran mentor, veteran peers, and researchers in collaborating the design of this mobile based peer-mentor modeling application. Second, we designed the system such a way that, it allows the system to collect data from peer being an anonymous user at the same time allowing them to access their data. iPeer is benefited from the collaborative design approach. But the anonymous user enrollment made the system design complex.
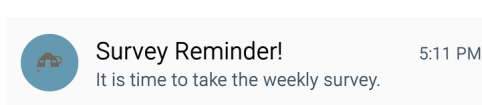
Figure 3.1: Check-in notification to complete the survey

3.5.5 Collaborative Design

Feedback from the veteran mentor, veteran peer, and researcher were carefully analyzed. We formed a team with researchers, veteran mentor and veteran peer. This team discussed their expectation from a peer mentor modeling system. UI component is carefully designed to reflect mentor and peers opinion including usability. Requirements are clarified how much anonymity the system requires. Involving veterans in the discussion process helped to increase their trust towards the system.

3.5.6 Evolution of Smartphone Application

The continuous discussion, analysis helped towards the evolution of the mobile application. Initially, we modeled the peer mentor application as a proof of concept. We implemented key features like check-in process, veteran summary report and user enrollment. But this initial implementation was unable to reflect better user experience. We collected limitation and expectation about the user interface for the initial implementation. We have taken into consideration about these feedbacks. After analyzing these feedback, we have redesigned the smartphone application especially its UI components. We worked with Crammer-Kasselt to redesign the mobile application. We redesigned the web application to be responsive following Google Material Design [11]. It allows the web application to be available for both mobile and desktop application.

3.5.7 Check in Process

From the collaborative design, we introduced check-in process. Every week the veteran peer has to complete two check-ins. The first check-in is scheduled on , second and final check-in is scheduled on Friday and Saturday. As of now each check-in process requires submitting a survey. Peers complete twelve check-ins in a six-week window. The veteran received standard notifications on their smartphone. It requests veteran to complete the check-in as shown in Figure 3.1.
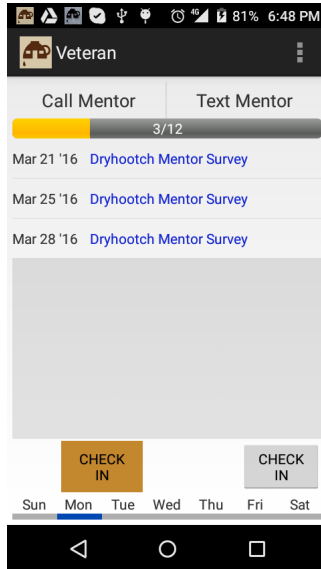
Figure 3.2: Initial implementation of check-in process
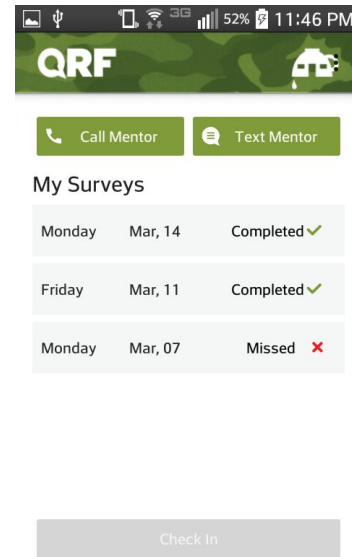
Figure 3.3: Current implementation of check-in process

The design of the mobile application evolved. Check-in process UI for initial version, Figure 3.2, and latest version, Figure 3.3, have large difference. The redesigned UI offers better aesthetics experience compared to initial implementation. It offers better user experience. Also, it improves the attachment with the application and the peer. Also, it is much more simplified. A veteran can see their progress with a single look.

Also contacting the mentor through call or text is simpler with identifiable UI components. User experience and usability increases veteran peer's trust and expectation from the smartphone application. It reduces the communication gap between a veteran peer and veteran mentor.

3.5.8   Veteran Progress

Veteran mentor expects to track the progress for their peer using the mobile application. They want to see the current progress comparing with the previous submission history. Also, mentor expects to know, whether the veteran peer missed, submitted the latest survey. A line chart shows each individual peer's progress over time. The initial implementation of the summary, Figure 3.5.8, was simple. The redesigned UI, Figure 3.5.8, offers the interactive and user-friendly experience. The initial implementation showed two separate survey completion status. It was confusing for mentors to identify first and second weekly survey. But this is no more
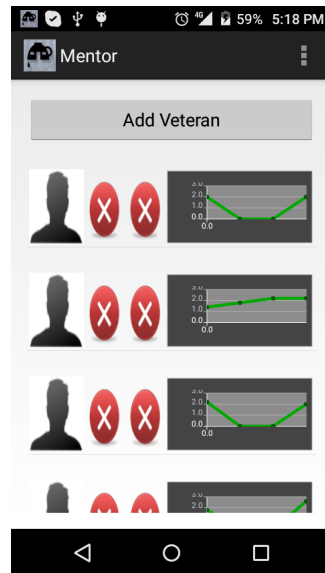
Figure 3.4: Initial implementation of summary of veteran peers
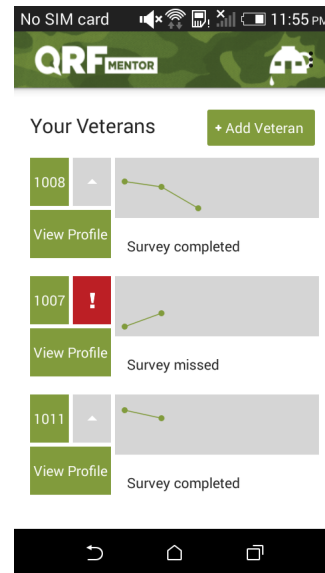
Figure 3.5: Current implementation of summary of veteran peers

the case for the new simplified design.

3.5.9 Veteran Survey Submission

The survey submission process is now simpler. A notification pops up when a new check-in become available. Veteran login using the application and tap the check-in button to start the survey submission process. The survey submission UI is much simpler and user-friendly compare to old UI. Now veterans are able to tap the selected answer to go to next survey questions. This tap gesture was not available earlier. Or the user can use "Back" or "Next" button to move between survey questions. They are able to go back to the previous question and change their answer. When the veteran is at last survey question, they can tap to select the last choice to submit the survey. After successful submission, the veteran will be back to the initial check-in screen. Figure 3.6 show the old survey submission screen and Figure 3.7 shows the new implementation. If we compare this two screen, we will see the difference between check-in screen, color combination, and aesthetic design.

We redesigned the veteran's detail information UI too. A mentor can manage the veteran's personal information from their mobile. Also, they can see the summary of all the survey submitted using the line chart. The mentor can click a survey from the chart and go to that completed check-in. It offers easy navigation between different surveys submitted by the veteran.
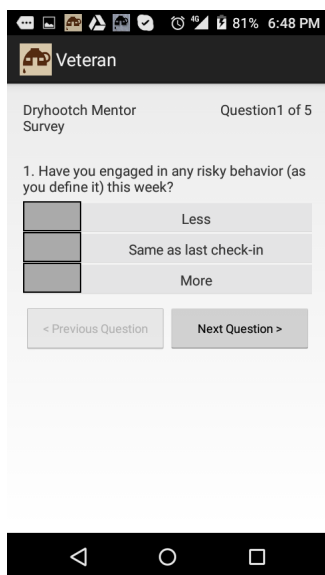
Figure 3.6: Initial implementation of survey submission screen
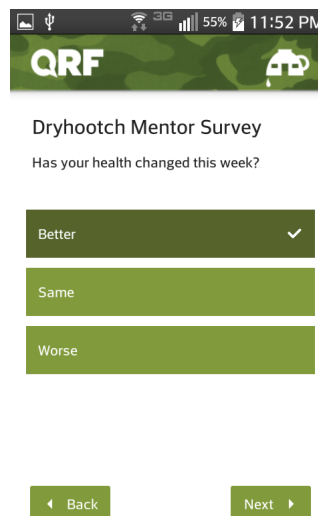
Figure 3.7: Current implementation of survey submission screen
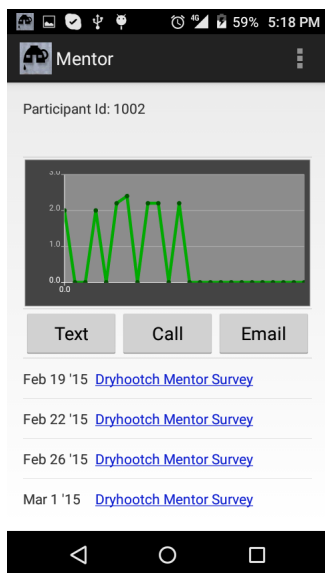
Figure 3.8: Initial implementation of veteran details
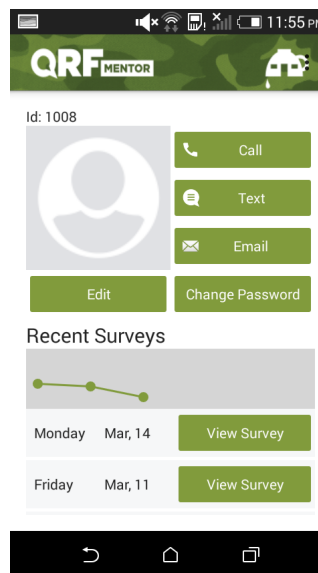
Figure 3.9: Current implementation of veteran details

This streamlined UI is more user-friendly, offers easy navigation, and better user experience. This, in turn, allow the mentor to work with more peers, compared to the initial version of the application. The Figure 3.8 shows the old veteran detail UI. And the Figure 3.9 shows the new veteran detail UI.
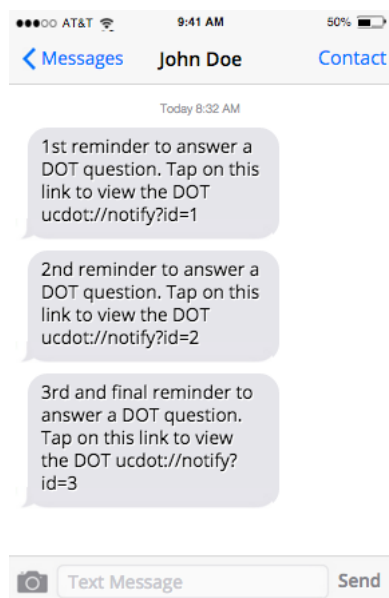
Figure 3.10: Sample text intervention notification to user

3.5.10 Generic Survey Submission User Interface

The survey submission and result UI from iPeer are the candidate for mCAT. The design of these UI components is generic. Future studies which use multiple choice question can use this UI component as a standard option. These components are driven by web service data. The component reads the data from web service and displays answer choices.

3.6 Promote Health Behavior Change

In the Self-Management study, we have developed simple intervention and assessment workflow. Volunteering participants enroll into the system for the one yearlong study. These participants require submitting surveys from various range. This range varies from four surveys per day to one survey per week. For each survey at most, three text notification are sent. Thus, it becomes in the range of 12 text message per day to 3 text message per week. Researchers analyze this varying range from user feedback. This will help to identify the most accepted intervention frequency. Also, the effect of collecting survey data worked as a marker point for throughout the study. This data analysis will help to identify if the intervention can contribute to promoting participant's health behavior in the long run.

This study sent text messages following predefined schedule. Participants have to submit survey data from predefined question set. Eligible users enroll into their system after the baseline

study. Participants have to fill out the survey on their 3 months, 6 months, 9 months and 12 months of the study. Figure 3.10 shows a sample text intervention notification to user.

3.7   Findings from Existing Research

As we can see, volunteering participant enrolls into the system. They receive intervention by motivational text or notification. Researchers collect survey data from these participants. Participants use the smartphone or web application to submit these survey. Also, mobile sensors send data as a form of a survey. Researchers analyze these data and evaluate a participant compared to the baseline study.

CHAPTER 4

REQUIREMENT ANALYSIS AND SYSTEM DESIGN

From previous and ongoing researches we have identified common key requirements. These requirements are discussed below.

4.1   Survey Creation

Survey creation is the key part of the system. It should allow collecting a various range of data. A survey may be a combination of a set of questions, it may be accumulated sensor data or both. To make it complex, the study may need to schedule these survey. mCAT should be able to support this variety of survey features.

4.1.1   Survey

Generally, a survey is questions based. Surveys like these have a set of predefined questions. Questions in a survey can be dependent on answering the previous question. Alternatively accumulated sensor data can be treated as a survey. As an example, the pedometer can collect step count for a day using the smartphone. The study can collect this step count for every day, to understand walking pattern or physical activity for a participant. These sensor data can be collected from the accelerometer, GPS, or even externals sensors, connected via WIFI or blue-tooth. Survey should be able to support these type of data too.

Participants may be able to to submit a survey any time of the study, and the same survey may need to be repeatated. Alternatively study may require these survey to be short lived, that is available for a certain period of time duration. Self-Management collected survey data from participant within a 45-minute window. iPeer collects data from the participants using two-day window. These surveys are closed, one the participant submit these survey, or time expire. There needs to be additional validation for the expired survey. This short-lived survey creation is needed to be scheduled.

To be more specific, there should be a scheduled survey generator. This generator will be triggered at regular interval and they will generate survey for the participant. There will be another scheduler running which will check if there is any survey schedule for that particular time and it will initiate the intervention process.

4.1.2 Question and Question Category

A typical question can be something as below. It is the simplest form of Yes/No single choice question.

"Did you take part in any physical activity today?"

Questions can be categorized. This categorization can be used later for intervention message. As an example if the answer for the previous question is "No" it can trigger a motivational intervention to the user.

Additionally, these categories can be hierarchical. An example is shown below.

- Physical Activity
  - Walking
  - Running
  - Cycling

4.1.3 Answers

The answer can be in the different types. The generic system should be able to accommodate all of these answer types. Standard form of answer types are as follows:

- Predefined Choice
- Yes/No Choice
- Number range
- Feedback

Now there is another challenge. From the server point of view, the system can handle them easily. But from a client point of view custom component needs to be used. As an example number, the range can be taken as a form of a time duration or a quantity. Even though the underlying data structure is same for both of these type, but user interface should be different for each of the questions and answers. For this reason, custom component design for the client should not be part of the standard feature set.

4.2 Intervention

Intervention can be done via text message or with the push notification feature in the phone. This notification can be delivered according to predetermined or random. A user may subscribe to his preferred message category. And the system should honor those preferences.

We identified common requirements like Message Group, a collection of Messages and user's message preferences. This requirement can vary depending on the research and should be able to use all of it or a small part of it. Also, these messages can be dispatched in various date and time depending on the intervention requirement. Another aspect is message group can be chosen depending on user's previous answer. mCAT tries to address these issues as an out of the box feature. Intervention can be done on following ways:

- Text message
  - Motivational text
  - Reminder text
- Push notification

The system should provide a database of intervention and motivational text. This text should be categorized too. It will allow texting to be related with question database. Also, it should offer users to choose from preferred motivational text category. A sample notification text can be as below

It is time to complete your weekly survey.

A sample text categories can be as below:

- Physical Activity
  - Physical activity instruction
  - Physical activity motivation
  - Physical activity tips

4.3   User Enrollment

The system should allow user enrollment. A user should be able to enroll into the system on his own or with the help of researchers. The system should be able to identify research participant or researchers. There might be a different type of user in the system as an example iPeer have mentors apart from the researchers and participant.

4.3.1   Zero Knowledge Proof

The user may want to enroll into the system without any personal identification such as email address or phone numbers. This scenario is not general enrollment workflow. Also, these users may need to recover their password. But without any personal identification system is unable to uniquely identify that user and not able to help recover their password. These are a Zero Knowledge Proof [34] problem. But still it is an unsolved problem.

This problem can be addressed by having a mediator, who can identify the user. The mediator can initiate the password recovery process on behalf of that anonymous user.

4.4   Security and Privacy

Generic mHealth tool should provide the minimum security measure defined by HIPAA compliance. Client-Server end to end communication should be encrypted. The public key certificate can help to resolve this issue. It should be used for all client-server communication.

Users' privacy and data security need to be addressed. There is security threat like SQL injection, XSS, and buffer overflow. Software framework can address most of this challenges, and any threats can be resolved to upgrade the framework. Also, user's credentials should be encrypted.

4.5   System Design

A good system design can assure the stability and long term support. The component-based design will allow having a small reusable module. The researcher can choose to prefer one module than another, not use some of it. Following sections discussed good software development practice needs to be followed.

4.5.1   Component based architecture

Allows to develop the modularized system. These are the reusable and extensible component. It allows the system to be easily customizable depending on research needs. The monolithic single solution is not customizable and hard to change since every module is tightly coupled. Component based architecture help to resolve these issues.

4.5.2   SOLID Object Oriented Design Principle

SOLID is the acronym for the five basic principle coined by Robert C. Martin. It is expected that if all of these principles are followed the outcome will be a maintainable software, and easily customizable.

4.5.3   Single Responsibility Principle

The component should be developed carefully to serve one purpose, and one purpose only. For example, the survey creation feature should be independent. For the mCAT, the survey module should be independent. Intervention module should be separate too. If we need the survey and intervention module to work together a different module should be developed.

4.5.4   Open/Closed Principle

This principle recommends that software should be open for extension and closed for modification. It is reasonable choice to have a generic feature. This restriction allows the current and future system to be stable and compatible to each other. The new feature can be added on top of existing feature.

4.5.5   Liskov Substitution Principle

It is about object oriented design of underlying classes and component for the system. It recommends using the generic base class or component against the specific implementation.

4.5.6   Interface Segregation Principle

It promotes simple small purpose interface compared to monolithic one. It helps components to be single purpose. mCAT follows these as an important requirement. Having it as basic requirements helps future extension easier.

4.5.7   Dependency Inversion Principle

It specifies how a component can be dependent to another component. It says components should rely on abstraction rather than concrete implementation. mCAT heavily rely on this principle. It helps to change implementation depending on the requirement.

4.6   Configuration Management

mCAT is highly configurable. It relies on dependency injection principle. The system is developed using Spring Framework [16] and Grails Framework [15]. Frameworks like these allow a component to be injected separately. Wiring these components is possible using configuration. This configuration can be changed externally.

CHAPTER 5

DEVELOPED CONTINUOUS ASSESSMENT TOOLS

5.1   iPeer: Social Engagement for Veteran

We have developed a novel peer mentor system in collaboration with Dryhootch, Medical College of Wisconsin and Marquette University. Veterans face difficulties with social reintegration when they come back from war. Dryhootch has implemented a peer mentor model addressing this social reintegration issue. With the iPeer research, we have modeled the peer mentor program as an mHealth tool. In this literature, we have discussed how iPeer emulated the peer mentor model as a continuous assessment tool, and how its web module serves the purpose of the generic component for mCAT.

5.1.1   Mentor Enrollment

The iPeer study evolved around the improving the communication overhead and delay between a veteran peer and a veteran mentor. A mentor guides his/her fellow veteran peer to address the social integration challenge. When a veteran come back home from a war zone after a substantial period of time it changes veterans ability to be a part integral, it impacts their ability to come back to regular social life. A well-experienced veteran can help his fellow veterans to overcome this challenge.

The tools developed from this research allows two set of users in the system, peer, and mentor. A mentor can enroll a veteran in the system using the smartphone application. The veterans added to the system as a peer feels threatened to share their personal identity information. So we designed the user enrollment and password recovery process with collaboration.

Enrolled veterans are needed to set their initial password. Without any personal identity information, it is not possible for the iPeer application to identify any enrolled veteran. It raises the issue similar to Zero Knowledge Proof [34]. We have tried a different approach to configuring the initial password. We found the mentor as a mediator can help to close the gap for veteran's personal identity information. After the peer enrollment, mentor application had to initiate the password reset process. The mentor application requested for password reset token on behalf of the veteran. After receiving the password reset URL, the application sends the password to reset

URL to the veteran as a text. From there the veteran can visit the URL and set or reset their own password. Still veterans find it difficult to use since password recovery process is completely different from a general workflow. This workflow is shown in the 6.3.

mCAT adopted this workflow as a standard workflow where privacy and security is an important concern for research participants. From here mCAT support multiple user groups, password recovery workflow with or without a mediator. This user enrollment module can be configured and used by different research according to their requirement.

5.1.2 Weekly Survey

iPeer implemented to a very good survey creation module. It was one of the requirement to create and manage survey from the web portal. Researchers can create a survey with a set of questions and choices. iPeer have implemented scheduled task which will schedule survey two times a week. These scheduled surveys are available for two days to complete. Veterans are needed to complete these survey so that their mentor can know their progress. mCAT have incorporated this module for survey creation.

5.1.3 Web Service

iPeer is developed following RESTful [9] web service. It is developed following HATEOAS principle. All resources are exposed using JSON format.

5.1.4 Release Automation

iPeer automated its deployment and release process. The web module is released using grails [15]. This release process is the part of the framework used to develop the web module. Android application is released using Maven. When a new version is released the veteran and mentor application get the notification. From their user can upgrade the application following standard process.

5.2 Cancer Survivors Monitoring Tool

We have developed the mobile application and web application to continuously monitor and motivate cancer survivors. We have developed this application in collaboration with South Dakota and Marquette University. One of the motivation to develop this tool is to help cancer survivors.

5.2.1 Intervention using Motivational Text Message

Also, it has very good message database. Using the web portal, a researcher can manage message and message category. This study has a set of motivational and instructional text message. Users are intervened four times a day with motivational and instructional text message. The mobile application allows the user to choose their preferred message category. A sample motivational message from the study is shown below.

> "If you can't fly, then run, if you can't run, then walk, if you can't walk, then crawl, but whatever you do, keep moving forward. - Martin Luther King Jr."

5.2.2 Continuous Assessment

The mobile application keeps track of users steps counts in the background. It synchronizes with the server every night. It gives a good indication to the researcher for the effectiveness of the rehabilitation program. Also, participants need to complete one daily survey and one weekly survey. Participants are notified about these survey every day.

CHAPTER 6

IMPLEMENTATION DETAIL

In this chapter we discussed how mCAT is implemented and what are the main component, features incorporated and tools used to develop this system. As we mentioned earlier this application used Spring and Grails framework, which means it runs on JVM and portable to any platform supported by JVM.

6.1 Architecture

The mCAT have two separate module. These two modules are independent of each other. One is focusing on web application and other is focusing as background services. These are two separate instances of micro service running parallel. Figure 6.1 shows the architecture of the system.

6.1.1 Microservice

Recently microservice is being the well-adopted software architectural pattern. It allows adding a new feature without requiring to change existing system. Another aspect is, mCAT is developed from combining three different system: Survey Module from iPeer, Self-Management EMA for scheduling and message database from the Cancer Survival intervention tool. Microservice allowed combining these three different systems. These separate systems use the single database to store all the information.

6.1.2 Three-tier Architecture

mCAT is designed following three-tier architecture. The idea is, a component in any layer, can depend on with the component from same layer or the layer below it. Figure 6.2 shows, how these three layers communicate with each other. The system is designed to minimize this There is
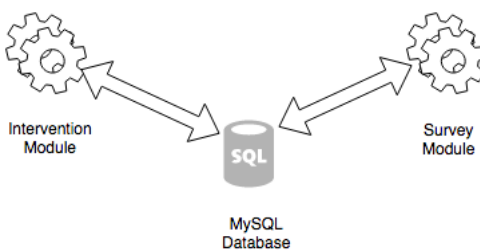
Figure 6.1: System diagram for mCAT
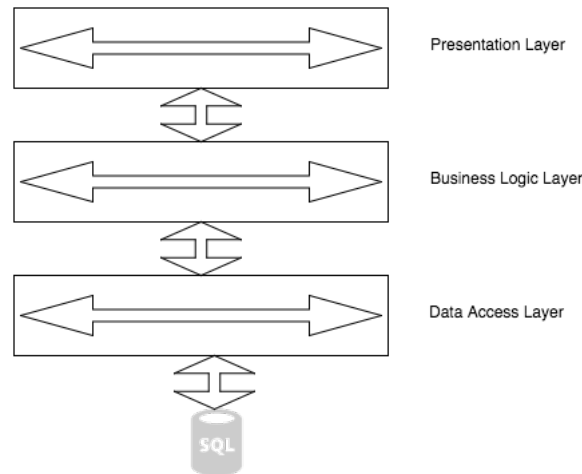
Figure 6.2: Three-tier Architecture for mCAT

no direct communication between these layers. These three layers are:

- Presentation Layer
- Logic Layer
- Data Layer

As an example, scheduling service component, a logic layer component, cannot depend on the presentation layer, rather it can depend on messaging service, or scheduling data layer component.

Model View Controller (MVC) Pattern

Also, mCAT follows popular MVC pattern. To make the system modularized and as independent as possible, controllers serves the purpose of the presentation layer component.

6.2   Web Portal

The web portal is the responsive web application. Web Module is developed combining the messaging module from Cancer Survival study and survey module from the iPeer study. It is mainly for the researcher to manage survey, manage motivational messages and enroll the new user into the system. Also, it has a rich web service developed following RESTful [9] architecture.

6.2.1   Survey

Survey is one of the key components for mCAT. Surveys are created with a set of questionnaire. These survey can be scheduled by a scheduler. A scheduled survey can only be submitted during the scheduled period. The mCAT provides SurveyInterceptor Interface 6.1

which can come into the middle of a survey creation process and take a decision on what to do for those particular survey. It has pre and post interceptor which can be used to intervene the survey creation or notify other API to take action.

```java
package mcat.api;

import mcat.entity.Survey;

public interface SurveyInterceptor {

    boolean accepts(final Survey survey);

    void preCreation(final Survey survey);

    void postCreation(final Survey survey);

}
```

Code 6.1: SurveyInterceptor.java

6.2.2 Message

There is a simple control panel for Message. Messages can be tagged. Tagging allows categorizing messages. Also, these tags can be used for tagging questions too. As of now only admin can manage this message database. Additionally, these messages can be system dependent. As an example participants can be sent weekly survey notification to complete the survey. Which is different to motivational text messages. Another aspect is, one text message is considered to be 160 character including all alphanumeric and punctuation. So when dispatching text message they needed to be processed separately for this.

Also, messages can be sent as an email. Users can be notified for their inactivity as an example. The system should be able to work with simple email template and send an email to users.

Apart from the message database, they can be externally configurable. The system can decide to have a fixed message or email template, and sent it to users as a notification.
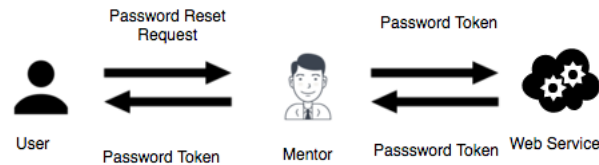
Figure 6.3: Password recovery workflow for anonymous user

6.2.3 Message Category

Message category helps to categorize messages. It serves three purpose, categorization of messages, support user preferences and finally relate with users assessment result.

The user may decide to prefer certain types of motivational messages compare to all message in the system. Similarly, researchers may have multiple control group. And each different control group may subscribe to a set of message category.

6.2.4 User Enrollment

User enrollment is important to support different control group and research role. As of now only admin can enroll a researchers or mentor into the system. Volunteering participants can be enrolled by admin, researchers or mentor as of now. Password recovery for the anonymous user is done using mentor as a mediator. Standard password recovery process is supported for the mCAT system.

Additional to general password recovery process, mCAT addresses the Zero Knowledge Proof with the help of a mentor as a mediator. Figure 6.3 shows the password recovery process for an anonymous user having a mentor as a mediator.

6.2.5 Authentication and Authorization

Authentication refers to validate users credential so that the user can access the system. Authentication can be stateful session based, or stateless using authentication header. As of now stateless authentication is supported using Basic Authentication. Work is in progress for token based authentication. Additionally, all communication with the client and server is done using HTTPS protocol, using the public key certificate. It protects communication between client and server from any "man in the middle" attack and improves the overall security of the system.

Token based authentication will allow the user to access the web service without providing any password again and again. It improves the user experience when using a

smartphone application, a general client application. Also, it improves security since, the user need not to provide the password each time, additionally, this token is refreshed with an interval.

Authorization refers to permission to secured resources. As an example, a participant should only be allowed to access his own personal data. mCAT relies on Spring Security framework for authentication and authorization. Using a standard framework helps to implement HIPAA Privacy and Security protocol. Additionally, the framework used for mCAT is open source. It makes sure any new vulnerability discovered is going to be fixed soon by the community and mCAT will be benefited.

6.2.6   Web Service

mCAT tries to strictly follow the open standards for web service. The philosophy behind this is, using open standard makes it easier for third party integration and leverages the learning curve on the open standard. mCAT web service adopted RESTful standard, which is simple and scalable.

All data exposed or accepted by the web service are treated as a resource. An autonomous client needs to know the initial endpoint URI. It discover other resources and so on. This discovery of resources is said HATEOAS. A sample resource for Mentor is shown on Code 6.2.

```
1  {
2      submissionTime: "2015-10-15T16:07:59Z",
3      score: 15,
4      progressDirection: 1,
5      links: [
6          {
7              rel: "self",
8              href: "http:///webservice/submission-summary/1"
9          },
10         {
11             rel: "schedule",
12             href: "http:///webservice/schedule/8"
13         },
14         {
15             rel: "veteran",
16             href: "http:///webservice/veteran/1002"
17         },
18         {
```

```
19              rel: "submittedAnswer",
20              href: "http:///webservice/submission-summary/1/submitted-answers"
21         }
22     ]
23 }
```

Code 6.2: Submission Summary Resource

HATEOAS

HATEOAS(Hypermedia as the Engine of Application State) is one of the main constraint apart from HTTP verbs. It specifies how the discovery of related resources needs to be done. According to HATEOAS, a single endpoint is what an autonomous client needs to know. From that endpoint, the client can discover more resources using link relation. The client may choose to visit those link resources and so on. When mCAT is designed HATEOAS was in the plan from the beginning. The initial endpoint for mCAT web service is shown on Code 6.3.

```
1 {
2     links: [
3         {rel: "version", href: "http:///webservice/version/latest"},
4         {rel: "issue", href: "http:///webservice/issue"},
5         {rel: "profile", href: "http:///webservice/profile/7/show"},
6         {rel: "survey", href: "http:///webservice/survey"},
7         {rel: "question", href: "http:///webservice/question"},
8         {rel: "choice", href: "http:///webservice/choice"}
9     ]
10 }
```

Code 6.3: Endpoint for mCAT

Link Relation

mCAT relies on Link Relation for exposing related resources. It is the descriptive way to specify a relationship between resources. Link Relation uses "rel" parameter to specify the relationship between resources. The "href" parameter specifies the URI to the linked resource. There is optional mime type parameter, which specifies mime type for the related resource. But it is omitted in mCAT web service. An example link relation is shown here in Code 6.4.

```
1 {
2     rel: "self",
```

```
3     href: "http:///webservice/submission-summary/1"
4 }
```

Code 6.4: Use of Link Relation in mCAT

6.3   Intervention Module

Intervention module is another key component for mCAT. It provides a set of Application Programming Interface (API) as Generators and Schedulers. This intervention module runs as a background service on top of Java Virtual Machine (JVM). This background service does all the automated task for mCAT.

It is a fact that a single system is not fully capable of to emulate requirement for all similar system. There should be a way that will allow researchers to incorporate those change in requirement to according to the study. Having these sets of API allows customizing the mCAT for a specific need for each specific research.

6.3.1   Schedulers

mCAT heavily relies on schedulers. Spring Framework with the help of CRON expression allows scheduling a job. Jobs can be scheduled

- Monthly
- Weekly
- Daily
- Hourly
- Minute and
- Second

In the Self-Management study, researchers needed to incorporate a complex intervention strategy. Participants are needed to submit 280 assessment throughout the one year study. A scheduler is used to generate all these assessment notification. Additionally, a separate daily scheduler went through all scheduled job for that particular day and generated time stamp when to submit that assessment. Finally a separate scheduler run on every 15 minutes. This scheduler dispatched text notification, reminding the user to complete the assessment.

Apart from that, Self-Management used to send inactivity notification, if the participants were inactive for 7 days, as a separate requirement. This notification is different from general intervention.

For iPeer, the scheduler schedules survey two times in a week. For the Cancer Survival research, motivational text messages are sent four times a day. There is daily scheduler running which notifies the participant to complete the daily survey. Similarly, there is a weekly schedule job, which reminds the user to take the weekly survey.

6.3.2 Generators

Generators are Abstract Factory Pattern. Similar to the pattern, they generate a notification, scheduled task etc. One of the SchedulGenerator API is shown on 6.5

```java
1  // ScheduleGenerator.java
2  package mcat.api;
3
4  import mcat.entity.Schedule;
5  import mcat.entity.User;
6
7  /**
8   * @author kowsercse@gmail.com
9   */
10 public interface ScheduleGenerator {
11
12     Schedule generate(final User user);
13
14 }
```

Code 6.5: ScheduleGenerator.java

6.4 Modules and Features Detail

6.4.1 Configuration management

mCAT is designed to be highly configurable. It allows the customization of the application easier. mCAT is modularized. A module can be enabled or disabled changing the configuration. Also, messages for intervention needs to be configurable. Messages can be read from a template using the configuration parameter.

Also, for scheduling CRON expression is needed. As an example, for Self-Management intervention is dispatched on every 15 minutes. CRON expression is shown on Code 6.6.

```
1  notificationSender.schedule=10 0/15 * * * ?
```

Code 6.6: CRON Expression for intervention dispatcher.java

6.4.2   Release Automation

The release process is automated. Uptime is important for a live application. It is expected that application will be live, even if there is an upgrade as long as possible, even when upgrading. Having an automated release process makes it faster to deploy the new version quickly. Since it is automated, it is less error prone, compare to the manual process. mCAT uses Maven build tool and plugins which help to automate this process.

6.4.3   Integration API

Integration can be done using two-way for mCAT. Web service or implementing API and configuring it. An autonomous client always relies on web service for integration. A well-written web service following the open standard makes the integration easy. A smartphone application consumes this resources from mCAT. mCAT provides API which can be implemented to change or extended behavior of mCAT's workflow.

A well-developed client application should be driven by the web service. To explain it simply, the smartphone application should depend on web service, to decide what to show in the UI and what action a user can take, rather than the client application asking deciding it for the web service. It leverages the responsibility more to web service. It keeps the responsibility separated with low coupling.

Pre and Post Interceptor

One of the idea to provide Pre and Post interceptor API. mCAT provides this interceptor for modifying these behavior. Code 6.7 shows the SurveySubmissionInterceptor. The SurveySubmissionInterceptor.accepts() method checks whether the current submission is needed to be intercepted by the component. If it does, at first, SurveySubmissionInterceptor.preIntercept() method is invoked. If all similar other interceptor proceeds then submission is accepted. After the SurveySubmission is saved into the database, post interceptors are invoked. They can decide what to do with the saved instance.

As an example, an interceptor can check if the score for a submission is below a threshold. If so, it can initiate an intervention for the user. This intervention can be a motivational text, or

notify the mentor to initiate communication with the peer. Interceptors like these can be very vital for customizing mCAT to adapt for different workflow required by the study.

```java
package mcat.api;

import mcat.entity.SurveySubmission;

public interface SurveySubmissionInterceptor {

    boolean accepts(final SurveySubmission surveySubmission);

    void preInterceptor(final SurveySubmission surveySubmission);

    void postInterceptor(final SurveySubmission surveySubmission);

}
```

Code 6.7: The interceptor for survey submission

Generators

mCAT relies on generators too. There are background service running which read data from the server after some interval. Later it decides whether to create any resources. As an example from the Self-Management research, a schedule generator runs in the background every 30 minutes. If a new user is enrolled into the system, it generated scheduled survey for the participant. the For iPeer study, a generator generate scheduled survey. These surveys remain active for two days.

6.4.4 Privacy and Security Module

Researchers and the User have access to their personal identification information. Again this personal identification information is kept separated from user's authentication information. It helps to improve security for personal data.

User Profile Module

User's profile information, which can uniquely identify a user, is managed separately from user's authentication information as we have discussed. If the study needs to support an anonymous user, it will then only be available to researchers. As of right now, only researchers

can enroll the user into the system. So they need to fill out the profile information as of now. After the user is successfully enrolled they will have access to their own data.

6.4.5   Data Export

Data export is done with the help of scheduler. For the Self-Management research, data export service run once in a week. It reads data from the EAV database and prepares it to be exported using CSV format. It helps researchers to analyze these data using tools like Matlab, R language and etc.

CHAPTER 7

APPLICATION OF THE MCAT

mCAT is designed to support study for behavioral and clinical psychology studies. We have shown earlier uses of mHealth research is effective for these studies. From the analysis of those studies we have proposed the generic continuous assessment tool, and from that requirement, we have developed the mCAT. Now here we will analyze how the newly developed system can be useful to these research.

7.1   Motivate Patient

7.1.1   Weight Loss Program

Patrick et al. [23] have studied text message-based intervention for weight loss. According to the study, participants are sent motivational, educational and questionnaires text messages from the set of 1500 text message database. Half of the text message requested a reply. Also, participants had the freedom to select their intervention window.

7.1.2   Physical Activity

The Self-Management study has promoted physical activity among elderly women. Initially, users were notified saying that, it is time to complete a survey. These survey questions can be created using the mCAT survey creation tool. The study asked a sample survey question as shown below:

"I have done something to increase my physical activity"

These notifications are sent at any random time of the day. From there the participant will have 45 minutes to complete the survey. If the participants complete the survey, the system sends second text notification 15 minutes later from first notification. Again if the participants fail to complete the survey another notification is sent 30 minutes later from first notification, asking the user to complete the survey. A scheduled job is running every 15 minute and users are sent these text notification.

7.1.3 Smoking Cessation

We have analyzed how mCAT can be applied to Smoking Cessation research done by Jami et al. [24]. This study had two major component, Web Site, and Text Messaging.

In the beginning of the study, the user enrolls into the system and provides their personal information. mCAT have the enrollment module which can help with this initial enrollment task. After that, they have to complete a survey as a form of the baseline study. Using mCAT a post interceptor for user registration can schedule the baseline survey for the user.

After the baseline survey is submitted the system determines participants smoking behavior. As an example it asks, if the participant smoke after the breakfast and if so the participants are sent text message intervening the user during that period. Again the post interceptor for survey submission can take action here. It can analyze the submitted survey and take necessary action on that.

Again users can see their progress, and smoke behavior from the regularly submitted survey. mCAT have the web portal where users have control to access their data. Users have to submit their smoking behavior related survey questions regularly. Then it determines when and what text notification is needed to be sent to users. Again these scenarios can easily be implemented with the help of interceptors for SurveySubmissionInterceptor.

The main component of this smoking cessation study is sending text notification. Text notification frequency increases as the user progress towards quit date. mCAT can handle this scenario using the daily scheduler.

Additionally, this smoking cessation can involve support person. The idea of using this support person is to motivate and help the participant to reach their goal. mCAT incorporated the concept of the mentor. It can notify mentor from the users survey result.

7.2 Monitor & Mentor Risky Population

7.2.1 Improve HIV Treatment Adherence

Benjamin H Chi et al. [2] in their HIV treatment adherence research by use of mobile technology. The study randomly selected a set of people as a control group for text-based intervention. The study compared patients' adherence to antiretroviral therapy effectiveness using the text-based intervention to standard care. Patients were sent weekly text notification

asking their health status. If no response is received within 48 hours a caregiver would initiate the communication with the patient. The text-based intervention found to be 62% more effective compared to the control group.

mCAT can be used here too. With the motivational text database and intervention feature, it can support the study as an out of the box solution. Obviously, this solution is a cost effective and much easier to implement for similar research.

7.2.2   Drug Addiction and Post Traumatic Stress Disorder

Fletcher et al. [10] have developed mHealth that is based on users cognitive behavior. According to the study, they have developed wearable sensor and mobile application to communicate with that sensor. The mobile application collect data from the wearable sensor, send to the cloud server. The application running in the cloud analyze those data and initiate intervention process.

mCAT can emulate the same scenario developed in this research. It can collect sensor data as a form of a survey. A post survey submission interceptor can intercept the submitted survey data. From there it can decide, when, how and whom to send intervention. The interceptor can decide of if the intervention needs to do immediately or later, or it needs to notify the mentor too for better counseling. mCAT can reduce design and development time offering the generic features.

7.3   Other Applicable Areas

We have discussed how mCAT is able to support existing research. It can be used for other research areas too. Some probable application area for mCAT is discussed below.

7.3.1   Depression and Suicide

There are people with depression and suicidal risk. Continuous support is needed for this risky population. mCAT can be a cost effective solution. It can emulate the peer mentor system, continuously assess those and give feedback. It will give the participants faith that, someone is their caring about, help is just one step away.

7.3.2   Youth Risk Behavior Monitor

mCAT can be used to study youth risk behavior. The smartphone is well adopted among youth. A study can survey trends of risky behavior among youth, and these data can be used to take preventive action. A simple survey notification can be sent to participating youths to complete the survey. Participants can complete the survey using their smartphone application. IT will make the data collection process easier and organized. Research like these will have more time to design the study and analyze the data.

CHAPTER 8

ANALYSIS AND LIMITATION OF MCAT

We have evaluated the developed system, in terms of integration complexity and learning curve.

8.1 Cost Estimation

mCAT is designed to be cost effective. Its main goal is rapid development and deployment of mHealth research for continuous assessment and intervention. There are different ways to estimate cost for the newly developed system. But here we want to estimate how much cost it can take to develop a new system on top of mCAT.

mCAT adopted the open-closed principle, it expects small changes in its core feature, favors customization on top of existing API and workflow. The cost to develop a new system can be analyzed using missing features or customization needed for specific research. Thus, it can leverage the cost to develop new system to following two categories:

- Learning mCAT architecture
- Adding new feature

8.1.1 Learning Curve

mCAT relies on open source tools and technology. It used popular language and frameworks like Java, Groovy, Grails and Spring Framework. The cost to learn these tools can be ignored if the developer is already familiar with these. Experts from different tools and technology need to learn these tools.

Apart from these developer needs to learn the small API to extend this application. Learning mCAT API should be easy since being a small application it offers a small set of interfaces. Also, web service specification needs to be understood for mobile and third party integration. Learning these API should be easy too. mCAT adopted HATEOAS which helps to discover underlying resources easy. Also, it eases complexity to introduce new functionality, with predefined workflow.

8.1.2 Customization

mCAT offers interceptors. Using these interceptors it can easily intercept the workflow and take action. It leaves an unlimited possibility for researchers to customize their system on top

of mCAT. Also, use of web service helps third party integration. mCAT offers the opportunity to use it in parallel to existing research. Its powerful intervention module can be used as an independent module to send a notification.

8.1.3 Integration

Mobile integration is made easier with the help of standardized web service. Researchers can develop new smartphone application easily following the standard. Alternatively, it is recommended to use developed peer mentor android application as a starting point. Smartphone application developed for iPeer research have core features like taking survey, user enrollment, password recovery for anonymous user. Also, these applications implemented effort of collaborative development from the peer, mentor, researchers, and development team.

8.2 Complexity

Customization and scalability of a software depend on its complexity of a software depends on two major property:

- Coupling
- Cohesion

8.2.1 Coupling

Coupling measures dependency among different components. If a parent component is dependent on other child components, it is hard to modify the parent component. It also increases the complexity of the parent component. It violates the Keep It Simple, Stupid (KISS) [33] principle. These monolithic components have a tendency to serve multiple purposes. For this reason, when designing an application it is expected to be low coupled.

mCAT achieved this low coupling with the Dependency Injection. It relies on a single purpose small component. Components are wired together using the component wiring framework, Spring Bean. Components are injected automatically by this framework. It reduces the complexity of initializing and wiring components with each other.

8.2.2 Cohesion

In software engineering cohesion means dependency of a component to itself. It is opposite to coupling. A good component demonstrates low high cohesion. It means a single

purpose depends on its own behavior to serve a purpose. It helps to change the components internal functionality without affecting other component relying on it.

One of the sample component used in mCAT is the text messaging client. This text messaging client relied on the third party web service. It had to prepare a batch of text messages, communicate using web service and finally detected success or failure of dispatched text message. But doing this verbose task is dependent to itself. Chaining any of its internal behavior does not affect other components using it.

8.3 Limitation

8.3.1 Generic UI Components

The mCAT does not provide enough generic UI components. The generic UI component library is not rich enough to show all question types. We have discussed challenges to design a UI component. More analysis and design decision will help to identify those key components. Both server application and mobile application should support these using web service as the communication medium. A researcher may want to see users submissions along with different question and choice types using the web portal.

8.3.2 Stability

We have not tested the system's stability. But from our current running solution, we have estimated its up-time to be around 99.4%, which is downtime of 2 days 4 hour 35 minute and 41.7 seconds in a year. There are third party tools which help to monitor the application. The mCAT should provide out of the box features which can report if the system is functioning properly.

8.3.3 Scalability

The system is not developed for scalability. It is designed to be single purpose and well-adapted solution. Its scalability is limited by the tools and technology used. Scalability of an application depends on the requirement of the specific features. Additionally, we need to determine the feasibility of scaling the application.

8.4 Fundamental Elements for mHealth Research

We have discussed features, requirement, and components that are common to research for mHealth research, especially for behavioral and clinical psychology. We have shown these

Elements	Description
Caregiver	Health-care representative to help patient.
Peer	A human subject who volunteer to participate in the research.
Mentor	Caregiver or researchers works with peer to understand their behavioral change.
User Enrollment	The user registration process
Continuous Assessment	Researchers regularly collect data from peers.
Intervention	An interruption is sent to user via text message or push notification.
Smartphone	The mobile device used as a communication medium between peer and mentor.
Survey	Represents a set of questions. Participants completes these survey.
Sensor Data	Data collected from Smartphone sensor e.g. accelerometer data.
Motivational Text	A text database with motivational text.
Survey Questions	Questions asked for continuous assessment.
Survey Choices	Predefined choices for a question.
Privacy	Users personal identifying information e.g. email address.
Security	Protect data collected from human subjects.
Authentication	Validate an user allow to access the system.
Authorization	Evaluate proper access right for the system.
HIPAA Compliance	Guideline to protect and share users data.
Anonymous Authorization	Trust an user without any personal identifying information.
Responsive UI	User Interface that supports different screen sizes
Scheduler	Services that runs on regular interval.
Interceptor	Services that listens to changes in the system

Table 8.1: Fundamental Elements for mHealth System

common key features exist in these mHealth systems. These systems need to address listed key

requirements. mCAT implemented these requirements combined all components to develop a

generic mHealth tool. We have summarized these elements in the Table 8.1.

CHAPTER 9

CONCLUSION AND FUTURE WORKS

9.1   Summary

We have shown how mCAT can help the implementation of existing research in mHealth area for continuous assessment and intervention. It will reduce cost rapidly and at the same time save time to implement the mHealth research tool. It has the potential to be a de facto standard for continuous assessment and intervention using mobile technology.

Being a generic tool, it has the opportunity to be used in different research. As an example, its powerful intervention module has the opportunity to create public awareness sending the educational text notification.

9.2   Impacts of mCAT

mCAT have the potential to be well adopted the simple one-purpose tool which can emulate intervention and continuous assessment. Any research was done that matches the strategy mCAT should be benefited from it. The more research uses it, the more maturity it will show in time. But one thing needs to be followed keeping it simple. It will be the best opportunity for researchers to focus on their data collecting and intervention strategy, instead of designing and developing the intervention and assessment tool. One way to measure the impact of mCAT can be adopting it and test it in within certain deadline. From there we will have feedback and add more feature to make it well accepted.

Imagine a situation where a rural area without the blessings of the health community. It is expected communication and health support is costly for those people. But if it is within the reach of the mobile network, continuous support for those patients can be reached with mCAT. A well-designed mobile application and simple text notification can make it easier for doctors and hospital to reach out to its patient. Its continuous assessment will be able to tell caregiver about the status of a patient. Both patient and caregiver will be able to save their valuable time with the automatic intervention and continuous assessment. It can be the next cost-effective alternative for providing health support. With its continuous assessment, intervention cycle will increase trust on among its user and caregiver creating a positive cycle.

9.3   Future Works

mCAT have its own limitation too. mCAT is yet to understand the meaning of the data collected from research. A machine learning tool can be integrated with it. From there it might be able to understand data and take decision e.g. initiate intervention or notify mentor. Still its question type is immature. Right now it supports only multiple choice answer. Future improvement of mCAT should address these missing question type and implement it with the highest priority as an out of the box feature.

Also from a mobile application point of view, it supports a limited set of questions type. mCAT can consider providing an API that will allow researchers to create their own question answer type.

Privacy and Security are always a concern for tools like these. Continuous improvement is needed here too. Data synchronization in the absence of network unavailability needs to be addressed. Also, it will require encryption of these data.

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APPENDIX A

APPENDIX

A.1 Dryhootch of America

A community organization formed by combat veteran for fellow veterans returning home to support them for social reintegration.

A.2 iPeer

The mobile based system that augment the peer-mentor program run by Dryhootch to help combat veterans for civil reintegration. It is developed in collaboration with Dryhootch of America, Medical College of Wisconsin and Marquette University.

A.3 Cancer Survival Program

The program run by the University of South Dakota in collaboration with Marquette University for cancer survivors. The mobile based motivational and monitoring tool helps cancer survival patient to motivate physical activity and track their progress over time.

A.4 Tools and Technology

mCAT used open source technology. This decision leverages the learning curve on existing solution. Following technologies are used mCAT.

- Language
  - Java
  - Groovy
  - Objective-C
  - HTML
  - JavaScript
  - CSS
  - SQL
- Frameworks
  - Spring
  - Grails
  - Google Material Design

- Android
- iOS

- Tools
  - Maven
  - Gradle
  - Git
  - Scripting
  - Tomcat
  - MySQL
  - Linux
  - JDK

mCAT relies on open standard. Relying on open standard makes third party integration easier. Researcher are able to integrate their existing system with mCAT only following they standard. Open standard followed to develop this system is listed below.

- RESTful Web Service
- HATEOAS
- Link Relation
- JSON Data Format
- HTTP Status Code
- Basic Authentication

A.5 System Monitoring

There are third party tools for system monitoring. These tools can be used to monitor health of the system. Some of these tools are listed below.

- Pingdom - Ping the web server from different continent of the world for regular interval
- Munin - Monitor resource uses of the system: memory, processing power, input-output connection, bandwidth, and etc.
- Nagios - Shows statistics of the system via web portal