Methods and tools for measuring correlation between mood and weather based on mobile experience sampling

HIWA BABAHAJIANI

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and Management

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Hiwa Babahajiani

Master of Science Thesis

School of Information and Communication Technology

Wireless@KTH Department

KTH Royal Institute of Technology

Stockholm, Sweden

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Examiner and Supervisor: Professor Konrad Tollmar

Software Engineering of Distributed Systems

hiwab@kth.se

2013-06-10

Abstract

Experience Sampling Methodology (ESM) is a research technique includes frequent reports of very recent participants' experiences such as mood and feeling. Captured data consequently could be analyzed for different purposes such as predicting human behavior in similar situations or studying psychological behavior. Studies in ESM are strongly dependent on participants' activeness. Responding to a set of repetitive questionnaires is a burden on participant's shoulder, especially in very first days of ESM, where participants had to answer questions via pen and paper.

Recently there has been a big interest in applying unique attributes of smartphones in conducting ESM studies. More specifically this project takes advantages of context awareness feature of new generation of mobile devices to provide an innovative means to assist ESM researches. To testify usefulness level of developed system in a real world context, this work will conduct an experiment to study correlation between weather condition and mood. To evaluate the usability of this toolkit, participants' experience will be measured and scored.

Keywords: Experience Sampling Methodology, Mobile technology, Context-Awareness, weather, feeling.

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Contents

List of Figures

List of tables

List of Acronyms and Abbreviations

API	Application Programming Interface
APP	Application
CAES	Context-Aware Experience Sampling
CSS	Cascading Style Sheets
ESM	Experience Sampling Method
ESP	Experience Sampling Program
GPS	Global Positioning System
GUI	Graphical User Interface
JSF	Java Server Faces
JSON	JavaScript Object Notation
MESM	Mobile Experience Sampling Method
MVC	Model-View-Controller
ORM	Object Relational Mapping
PC	Personal Computer
PDA	Personal Digital Assistant
SaaS	Software as a Service
SMS	Short Message Service
UI	User Interface
XML	Extensible Markup Language
XP	Extreme Programming

Chapter 1

Introduction

In first chapter of this thesis report, the reader is introduced briefly to the research area along with most challenging problems of the field. Afterwards, the project's main purposes and goals, sub-goals, research questions and research methodology are presented.

1.1 Overview

Feelings and moods have quite powerful importance in predicting human behavior. One of the most popular methods in psychology to study human mood and feeling is experience sampling [1]. Experience sampling methodology includes frequent and almost immediate reports of very recent experiences from the same participants for a period of time to study their behavior in specific situations.

The focus of Experience Sampling Methodology (ESM) is on fluctuating variables over the time. This is way ESM is become increasingly popular in health, psychology, and clinical. Health researchers call ESM, ecological momentary assessment. They use this approach to measure psychological variables such as blood pressure and heart rate. Nowadays ESM is going to be one of the outstanding techniques to measure thoughts and feelings in social interactions like job satisfaction and citizenship behavior [2]. Applying ESM, organizational and social researchers try to find a correlation between thoughts and feeling, behaviors and outcomes and environmental situations [3].

1.2 Introducing ESM through a Simple Scenario

To have a better understanding about ESM and the idea behind it, firstly we are going to consider a simple scenario. Michael is 17 years old and suffers from schizophrenia. Michael's parents say that his behavior is changing considerably from time to time during day. His doctor wants to find out when and why Michael's mood is changing, so he provides Michael a booklet containing some iterative questions generally regarding his state of mind. Michael should answer to these specific questions 4 times a day; after waking up, before lunch and dinner and before going to bed. Besides answering these questions for 10 days, Michael should also note his feeling and mental posture briefly. Doctor will dig out his responses and compare Michael's behavior in different situations to realize effective causes which boost his schizophrenia. This scenario represents a routine example of an ESM experiment. Based on provided reports from participants, researchers can achieve and record feedbacks, experiences or any kind of human reports about a specific context in everyday life and consequently analyze these reports.

There are other research methods such as interviews, questionnaires and observations. For different contexts and based on research goals researcher can opt one of these methods [4]. There are some similarities between ESM and these methods, especially questionnaires. Indeed ESM consists of frequent number of questionnaires. Compared to these research methods, ESM is very effective in some research contexts but ESM has its particular challenges. In next sectors of this chapter we will discuss problems faced with Experience Sampling Methodology.

1.3 Problem Statement

However Experience Sampling Methodology has unique dominance in some research fields and contexts and even sometimes it is not possible to study the phenomena without applying this methodology, but it has its pitfalls and disadvantages which sometimes make the experiment too expensive to conduct. Imposing high burden to participants is the biggest pitfall of ESM [4]. If participants are invoked by signal to response to ESM questionnaire 4 times a day, they might not have enough time to response on each signal, or they might even ignore the signal if it is disrupting them.

On the other hand, ESM needs a lot of time and resources to design, publish, collect and analysis experiments. Participants' time and location are two important parameters which should be carefully monitored during experiment period by researchers.

Emerging Mobile technologies and ubiquitous smartphones have evaluated and facilitated ESM techniques and methods in many aspect. This work firstly review former works in weather-mood studies and attempts to show how context-awareness property of modern mobile devices simplify and improve conducting ESM researches in weather-mood studies.

1.4 Research Questions

Most remarkable challenges and pitfalls regarding current methods in ESM are stated in ESM challenges and pitfalls sector. Furthermore in next chapter through "Related Works" (See 2.3) previous ESM applications and solutions are described and their disadvantages will be reviewed. Considering limited time of this master thesis we have tried to practically present an alternative mobile approach to conduct experiments based on ESM. The research questions that motivate and challenge this research are:

1. Does context-awareness of mobile technology affect usability of experience sampling experiments?
2. If yes, to how extend it can improve user experience factors such as "ease of use" and "time on task"?

To answer these questions a new MESM system consists of a web server application called AskBird and an Android native application called FeelDroid have been implemented and integrated. In order to testify and measure usability factors of the system, a real experiment will be conducted. Weather has been stated as the context of the experiment. ESM has a fundamental role in researches regarding correlation between weather and mood. In next chapter, current research gap described and practical challenges in running weather context ESM experiments will be stated (See 2.4). During the real experiment we are trying to answer these the sub-questions:

Combination of AskBird-FeelDroid provides location, time and weather awareness. We would like to observe does context-awareness specification of this work affect weather-mood researches?

Consequently, if mobile technology decrease pitfalls of current ESM studies in weather, to how extend it helps to improve positive user experience scores such as "time on task" and "ease of use" and decrease negative user experience scores such as "participant disturbance"?

1.5 Research Purposes and Goals

The ultimate goal of this thesis work is to take advantage of modernistic mobile technology on smart phones to conduct ESM researches by

implementing a hybrid native-web application by integrating two application called *AskBird* and *FeelDroid*. After implementing and integrating these toolkits as a new implementation of a system to run weather-mood studies based on MESM, the usability and power of the toolkit should will be testified to see to how extend it can amend current pitfalls and challenges in in running ESM studies. However the toolkit should be able to conduct ESM researches on different contexts, to execute a practical study by toolkit, a specific context should be set out. To achieve this, it is necessary to define a specific context for the test. One of the most challenging and complex contexts to get user experience is weather and there have been different studies about the relationship between weather and human mood. Supporting reasons for this decision is going to be discussed in next pages.
Moving from general to specific goals, the goal of this thesis project can be split into these parts:

a. Proposing a MESM approach to measure correlation between mood and weather.
b. Developing a toolkit that contains the core ideas of the proposed approach.
c. Validating the proposed approach by real experiments.

1.6 Structure of This Thesis

This thesis work is principally classified into three categories; academic studying on experience sampling methods and related works to it in a theoretic manner , and practically implementing an open source software and running an experiment on this toolkit.

Thesis report is presented to the reader in 6 chapters. Chapter 1, “Introduction”, represents an overall description about research area and addressed problems and defines the research questions and goals. Chapter 2, establishes the foundation required to understand ESM and related problems comprehensively, and reviews former works in ESM and MESM. Chapter 3, “Methodology”, describes which methodology has been selected for this research, examines the requirements of developed application and offers a detailed specification about different applied technologies. Chapter 4 shows how implemented system is testified through a real experiment. This chapter shows several steps in order to design, scheduling and run the experiment. In chapter 5, captured data through experiment will be analyzed and different user experience factors such as time on task and ease of use will be measured. The last chapter, “Conclusion and Future Work”, summarizes the conclusions reached as result of the work performed during this thesis project. Finally, some future works are recommended.

Chapter 2

Background

This chapter provides the background knowledge required to understand the research that was conducted. A reader is introduced to the concept of experience sampling methodology comprehensively, its advantages and disadvantages and then a description of several former works relevant to this thesis work is provided.

2.1 Experience Sampling Methodology

Experience Sampling Methodology refers to a survey method of data collection mostly used in psychology to understand user experience. ESM asks participants to respond to repeated questions at certain times. Participants' temporal experiences are recorded and studied by researchers.

ESM can be used for many different study contexts which mostly related to participants real time mood, feeling and emotions [5]. ESM is specifically useful and applicable for researches that last long for weeks or even months and involves capturing short responses from participants. Collected data from participants is a very rich resource to be evaluate and analyzed since it provides within and between participants comparisons [1]. What is the reason behind different moods for a participant in exactly same location and same time at day? Indeed it is a hard question to answer, but ESM at least provides this ability to inspect these differences.

2.1.1 Why to Use ESM?

ESM has been known truly as the "gold standard" for the in-situ measurement and evaluation since it supports recording user experience right at the moment of occurrence [6]. But what is the importance behind recording user experience in-situ?

By having this golden standard, ESM reduces the bias and error that is naturally exists in retrospective transient experiences. Retrospective behavior and feeling reports can be influenced by different factors, like salience, current effects, and recency and memory faults [3]. The contamination level of these factors increased over the time. Without a doubt because feeling about a same context changes over time if we do not get the feeling in-situ we might lose it. There have been done different studies to see the contamination effect of time and its related factors on retrospective reports. Almost all of these studies insist that retrospective summery reports cannot provide valid data about momentary points in the period of study. Based on a research on a group of individuals with schizophrenia, researchers found out that while retrospective summary reports of the severity of certain symptoms compare relatively well with average momentary ratings, they are limited in their ability to capture variability in one's affective or psychotic experiences [7].

ESM is not limited only to between-person investigations. Another important reason to use ESM tools and techniques is that they are specialized to record dynamic within-person activities that only revealed over time [8]. Variability in personality is an important factor to study individual's behavior and frequent-based personality assessment is recognized as a proper way to achieve variability information consistently [9]. ESM provides the ability to measure fluctuating variables by asking frequent questions and then find out the relationship between these variables within related situation, for instance, the relationship between level of happiness and weather condition.

2.1.2 Key Decisions in Conducting ESM

Indeed, there are many different key decisions in conducting ESM. Here, we only review some outstanding factors in planning and running ESM researches briefly. As mentioned before, ESM is a method to collect user experiences frequently. Based on this shortened description, ESM researcher should decide cleverly about these challenging factors:

a) **ESM scheduling;** after defining context and related questions to ask participants, ESM researcher should specify for how long and how often the study must be conducted. Frequency is a very challenging key in designing ESM study. Questionnaire repetition number per day is in most cases between 2 to 12 times [10]. Estimating research sample sizes properly is another way to help determine the frequency and period of the study [1]. Finding a proper repetition number is a very important factor to consider. Because there is a tradeoff between number of repetitions and participants' contribution. Considering less repetition number and also limiting the number of variables which is an emergent of producing closed question reduces the burdensome

nature of the task. In this case researchers are likely to narrow the gap between those who participate and those who do not or cannot [4]. One way to decrease frequency is to increase the experiment length. So instead of having an experiment with frequency 10 times a day for 10 days, a researcher might alternatively set the frequency to 5 times a day for 20 days.

b) **Data collecting strategies;** a key decision in ESM research involves the plan for sampling moments of experience, including how ask and prompt participants for reports. Three distinct types are available [11]:
   1. ***Interval contingent* reporting**: in this approach participants should answer at predefined time intervals. This approach is less intrusive relatively since this approach provides predictable timing.
   2. **S*ignal contingent* reporting**: This approach requests reports at varying times each day. In other words, participants are invoked to respond at a random time. This approach is appropriate for studies with higher frequency, however it takes more burdensome for participants because of unpredictable nature of this approach.
   3. ***Event contingent* reporting**: in this approach participants should respond on occurrence of a pre-designated event. This approach enable the research to focus on interested events and eliminates asking question when it is not necessary. This approach lighten the participant's burden but it is the most complex approach to implement [3].

2.1.3 ESM Challenges and Pitfalls

However ESM has unique dominance in some research contexts, specifically in studying human experience, researchers should consider potential pitfalls of running ESM studies.

ESM expects participants to respond to a questionnaire 2 to 12 times per day. Clearly it imposes high burden to participants compared to other research methods [6]. Even with short questionnaire containing 4, 5 questions that only takes 3 minutes to complete, if the frequency is set to 5, during two weeks, participant are supposed to answer 5*14*5= 350 questions over the experiment which might take more than 3 hours collectively.

Moreover consuming a lot of time for participation, participants are irritated multiple times a day by ESM signals. Even if participants take part in a pre-scheduled experiment, these continuous signals make them weary and irritated. All of these problems in participants' side, lead to low compliance

[12]. Leaving the study by participant is the most fatal incident since ESM depends on participants' ability to articulate ongoing experience [13].

On the researcher side, the ordinary ESM requires extensive investment of time and resources in order to distribute questions, collect and analysis responds [14]. Researchers need to monitor participants and apply proper strategies to get accurate information about their location and time [13].

2.2 Mobile Experience Sampling Methodology

Emerging Mobile technologies and ubiquitous smartphones have evaluated and facilitated ESM techniques and methods in many aspects. Mobile is the most accessible ICT medium that can do everything the previous six media can do. Mobile users can get different services from their mobile from browsing Internet, to location servicing and to read and publish multimedia messages and specifically participate in repetitive questionnaires efficiently.

There is no need for pen and paper anymore to participate in ESM studies, but it is just the very trivial effect of using mobile devices in ESM. In fact, mobile technology has had an evolutionary effect on Experience Sampling Methodology by a specific functionality of mobile devices "context-awareness". This feature permits researchers to obtain extra information from users automatically, detected by GPS services or sensors connected to a mobile device [15]. Intelligent applications and embedded sensors in stylish mobile phones enable these devices to automatically extract different sorts of data about their users like location, blood pressure, heart rate, and even weather condition in user location.

Mobile technology decreases the burden of Experience Sampling for the participants. As mentioned before, increasing number of questions has negative effects in ESM. MESM decreases number of questions intelligently. For instance there is no need to ask participants about their location, since mobile application can provide this information through GPS in background and send it to researcher.

Another benefit of MESM is that sampling can be conducted in a client-server system, this means that studies can be conducted, and analyzed in a very large scale compared to traditional ESM. Furthermore responds immediately imported to servers, and in this case researchers can monitor level of participation [11].

Question distribution, real time data capturing and data analysis is now easier by applying specific characteristics of mobile devices such as context-aware property. However beside all of these benefits of MESM over ESM, some problems of ordinary ESM is still inherited by MESM [14].

2.3 Related works

In this section, some existing projects related to Mobile Experience Sampling will be reviewed and their specific features and disadvantages be evaluated.

2.3.1 CAES

CAES stands for Context-Aware Experience Sampling, is one of the very first projects concentrated on applying ESM on PDAs, designed and implemented in pure C++ by Massachusetts Institute of Technology (MIT). The initial goal of the project was "to gather data on the activity of people as they go about everyday life" [16]. CAES was used in several projects like Studying interruptions, Context-aware interventions, recognizing activities of daily living from sensors.

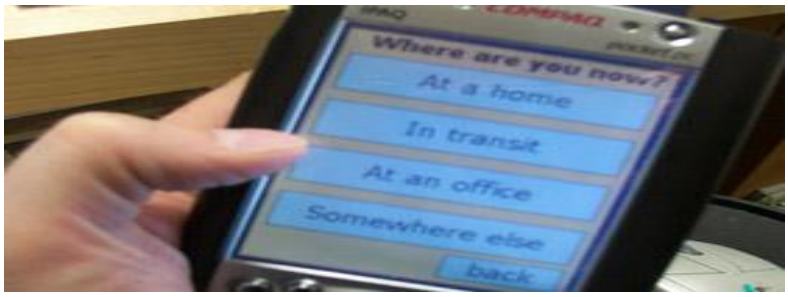

Figure 1: an early prototype of CAES

One of the problems with CAES project was that however it could work with plugins like cameras, GPS, and HR monitors, it was not possible to use all of these devices at the same time. Another problem with this tool was that CAES was designed explicitly for iPAQ PDA devices running the Microsoft PocketPC operating system and it was not possible to run the toolkit on other devices without modifications [17]. By emersion of modern smartphones development team left the alpha version of CAES and started cooperating on a new MESM toolkit called *MyExperience*.

2.3.2 MyExperience

This work was started in 2005 as a cooperation between Intel Research, Seattle and the University of Washington. The primary aim of MyExperience is to collect sensor-based location information along with self-report data on a user's cell phone [18]. It supports both ESM and context-aware experience sampling and can capture subjective and objective data from different sources of data like sensors, GPS, camera and questionnaires.

One of the smart privileges of MyExperience is in using XML as a lightweight, language independent and easy to use and read code. Furthermore it supports all popular sampling strategies in ESM (see Data collecting strategies in 2.2) and also combination of these strategies.

Figure 2: MyExperience captures sensor data via Bluetooth

Beta version of MyExperience supports 50 different built-in sensors. MyExperience efficiently uses wireless technologies like Bluetooth to capture data from sensors. The only problem in this case is that wearing or carrying sensors is not pleasant for all participants. Captured data from sensors are time stamped and stored on mobile device local database. During a synchronization process, this data will be transferred to server. In some cases cost of storing huge amount of data in mobile memory and synchronization phase are unignorable.

2.3.3 ESP (The Experience Sampling Program)

ESP is a free software designed for Palm Pilots to run scientific researches and capture data based on ESM with the ability to display questions, receive responses and calculate reaction times [19]. ESP supports three main data collecting strategies of ESM (see 2.2) which are fixed, random and event contingent sampling. At first glance ESP seems to be a powerful MESM toolkit, but it suffers from some distasteful problems. ESP is highly platform

dependent, since it is only running on Palm PDAs. Since there is no support available from developers of ESP, there is no way to install and run the toolkit on modern mobile devices and participants have to carry old Palms with them all the time through experiment. ESP occupies whole processing unit of mobile device and there is no ability to run other programs on the device simultaneously during the experiment. This is not acceptable by mobile users nowadays to use such a boring program. Furthermore there is no wireless ability available to transfer responses from mobile device to researches side and participants have to be present in laboratory and give out the results to researchers manually [20]. This is a huge burden on participants' shoulder to do. Since there is a gap between publishing questions, responding and gathering data at researcher side, there is no way to track and control ongoing researches. For all of these reasons it is not equitable to use this toolkit.

2.3.4 An ESM app to study awareness needs of busy families

This application specifically designed to study communication needs of working parents concerning awareness of each other's location and activity during day. 20 people (10 men and 10 their wives) recruited as participants. The main difference between this project and others work in ESM, is that in this project participants could design the experiment themselves and decide what kind of information they would like to share (Figure 3). The application enables the participant to set frequency and time they would like to receive the questions [21]. Every night during the investigation, participants had to connect their mobile device to internet to synchronize data. Unlike other ESM toolkit participants could modify their answers by logging to the website.

Figure 3: How participant can choose different contexts to share

However result of applying this application was satisfying by researchers, but it this application is too specific and it is not possible to use it in other ESM related researches. Application only supports interval contingent strategy and by giving authority to participants to design experiment themselves it has modified the concepts of ESM to a large extend. This project put double burden on participants by asking them to design experiments.

2.3.5 Pocket Bee

Pocket Bee is a mobile toolkit to support dairy and ESM studies based on Android platform. By implementing "Native application-Server" structure, one of the outstanding features of Pocket Bee is "instant network synchronization" which provides high level of monitory and control over ESM studies. By analyzing upcoming results from participants via a web-based control center, researchers are able to improve the direction of the study dynamically by creating new questionnaires during ongoing studies [22].

Figure 4 : Pocket Bee Client side UI

As mentioned, Pocket Bee project has two main component. Immediate data storing on MySql database and further analysis of data is done at server side. On the client side Pocket Bee integrates an Android native application interacts with participants in order to capture their experience via a friendly UI. The architecture of Pocket Bee makes it a successful ESM distributed system by having a powerful functioned backend control center and a native Android application which can be used by every current Android devices.

This part of report will be finished by mentioning the fact that there other similar mobile toolkits like PsycLab Mobile, PMAT, Entyware, D'PUIS and Reconexp [23] which work almost in the same way based on ESM. Most of

these toolkits are designed for research purposes and they are out of use by the end of their mission [5].

Studying previous projects and their characteristics, especially the Pocket Bee project, was a great inspiration in designing and implementing *AskBird* and *FeelDroid* toolkit. The architecture, structure and main component of this project will be described in next chapters in this report.

2.4 Research Gap in Weather-Mood Studies

During exploration into different experiments and investigations on different contexts based on ESM, several works found with the aim of track down relationship between mood and weather. Correlation between weather and mood has been a hot research area in psychology science. ESM is one of the most suitable methodologies to study mood-weather correlation, however almost none of the previous works used mobile technology unique and outstanding properties. Analysis these works shows that MESM has the potential possibilities to smooth the way of conducting weather-mood researches vigorously. Context-awareness property of smartphones provides a sole opportunity in this way. Below the most challenging and limitative complications in weather-mood researches is discussed and in the next chapter the MESM proposed solution to cover these problems will be presented.

2.4.1 Mixed Results in Weather-Mood Researches

It is commonly believed that weather has significant impact on different aspects of human life. For instance it is a mostly expected opinion that people are happier in sunny days but they are depressed in cold days. There have been different studies about the relationship between weather and human mood, however only few of them have explored the relationship between weather conditions like temperature, humidity on mood [24]. Based on a study done by *Persinger*, he found out mood scores were inversely related to relative humidity and positively to longer sunshine hours, however these correlations were nonsignificant [25].

Practical investigation about Correlation between weather produced mixed results. Some studies like research done by *Denissen*, showed no significant main effects of daily weather parameters like sunlight, air pressure and temperature on positive moods like happiness [26]. On the other hand, *Mark*, and *Clore* (1994) found that sunny and warm days were associated with more heuristic and less systematic processing than cloudy and cool days [27]. This inconsistency comes from many different factors influence on the association between weather and human mood and behavior. Anomalous results prove

that mood is itself difficult and complex to measure, in particular when it is associated with biometeorology.

2.4.2 Practical Challenges in Weather-Mood Researches

Beside limitative problems which naturally exist in weather-mood researchers, there are some technical obstacle which affect investigations related to weather context. Although coping with innate problems is severe, rectifying technical obstacles is more practicable. Studying previous works in this field these technical problems are figured out:

1. **Size of subjects group:** In some prior experiments population of the participants are around 10 to 30 people [24] [25] [28] [29]. Since there are very different variables affect correlation between weather and mood, this size should be greater to have accurate results. Indeed researchers may know that but the problem is increasing the participants' population decreases the level of control and supervision. Researcher should take care about all participants' locations to find out weather situation for each particular participant. Each time a participant changes his/her location there should be a mechanism to aware researcher to get participant's valid weather properties. Increasing the population number has a direct effect in increasing the cost of publishing and gathering questionnaires.

2. **Weather condition during experiment:** Weather situation fluctuation is one of the significant factors to have accurate result of weather-mood correlation experiments. Conducting the experiment in stable weather condition cannot satisfy the fundamental conditions needed to validate the experiment. For instance if the researcher runs the experiment for 2 months in winter and most of the days the weather is relatively cold and cloudy, there would not be a comparison between warm and cold days. On the other hand it will be boring for the participant to respond same questions with same answers and at the same time the repeated answers in stable weather condition for a long time, does not bring any new consequence to light. It would be very efficient to publish questionnaires whenever there is sensible fluctuations in weather conditions.

3. **Location dependent:** Weather is trivially dependent on location and the importance of precise location in weather related experiments is unignorable. In the simplest and ideal case, subjects are stabilized in a particular location, however in reality it is not practicable to fix participants locations. Therefore researcher should be completely eagle-eyed about subjects' location. In a large scale experiment where

subjects change their locations frequently how the researcher should be notified about the subjects' location modification and consequently achieve weather condition in participant's new location?

4. **Subjects outside time:** One of the remarkable challenges with current methods and tools applied to association between weather and mood is that researchers cannot find out time duration passed by subjects outdoor. Even if participants provide their current location to researchers, it does not clarify for how long they have been in that location. Obviously it is not applicable to ask subjects to calculate outdoor time durations every time they want to respond and even if they do it is not accurate. In Jaap J. A. Denissen research on "The Effects of Weather on Daily Mood" he mentioned "we failed to assess the time that participants spent outside, which may have emerged as an important moderator of the effect of weather on mood [26].

5. **Real time responds are important**: Since weather condition changes over time subjects should respond to questionnaires in real time. There should be a mechanism to guarantee participants' response time is valid. There should be a mechanism to check whether responds pass deadline or not. In addition it is also important to check the weather in the real time of respond especially in very fluctuating weather conditions.

These are most challenging technical problems in order to run an ESM study when the context is weather. The idea is to provide a solution to face with these problems by implementing a toolkit based on MESM. In next chapters this solution will be presented, testified and evaluated.

2.4.3 How Mobile Technology Can Help Weather-Mood Studies?

Mobile technology provides some unique features that can solve some challenges weather-mood experiments are currently faced with. Here we claim how a weather-aware system can relieve researchers to run the weather-mood based experiments properly. Applying this hypothesis, we are going to implement AskBird-FeelDroid system and testify its usability through an experiment.

1. **Size of subjects group:**

   AskBird as an internet based toolkit provides a dynamic platform for running different sort of frequent experiments. Subjects can register on the server from their native mobile application. This project is location-aware and there is no need to monitor subjects' locations by researcher. Indeed

from researcher view, AskBird works location independently. For researcher, there is no difference at all from each point on earth the subject participate in the experiment, since system automatically gets current location and weather condition for every particular subject. Mobile participants' location is updated and recorded in the exact time of submitting the questionnaire. Reducing level of supervision, decreases burden on researchers' shoulder so they can run the experiment with large population size.

2. Weather condition during experiment:

It was described that running the experiment in sable weather conditions is a boring activity for participants and furthermore it produces redundant data for researchers. So sometimes researchers prefer to get responds from subjects when there are fluctuations in weather conditions. As described before one of the data collecting approaches in ESM is event contingent (See 2.1.2). However AskBird is only interval and signal contingent it is possible to add event contingent property to it in a way that subjects are invoked to take part in the experiment when there is a predefined minimum of fluctuations in weather conditions.

3. Subjects outside time:

Researchers are likely to know are the subjects participating indoor or outdoor. Mobile devices have provide verity of ways to check whether the subjects are in open area or in close areas such as offices or houses. One simple way is to use smartphone thermal sensors and get the current temperature of the mobile device and compare it with usual indoor temperature or more accurately compare mobile device temperature with current weather temperature. Obviously when the difference between device temperature and weather temperature is high it is in most cases a reason that subject is indoor.

Chapter 3

Methodology

Until now, we have introduced ESM and effective role of mobile technology to conduct ESM studies resourcefully. More specifically some technical challenges in running weather-mood researches based on ESM, have been explained. This chapter explains how this thesis project tries to achieve defined research goals (See 1.4) to develop a MESM toolkit to run weather-mood studies and then evaluate presented approach by executing a practical study and analyzing its results.

This research has engineering nature. The research methodology selected is *Design Science* [30]. Design science is an outcome-driven methodology and this research is perfectly matches most aspects and phases of design science. These are steps and phases of Design Science Research Methodology which this work structured based on it:

1) Problem identification and motivation (See Chapter 1).
2) Define objectives for solution (See Chapter 2).
3) Design and Development (See Chapter 3).
4) Demonstration (Demonstrate use of developed toolkit in real test, (See Chapter 4)).
5) Evaluation (See Chapter 5 and Chapter 6).
6) Communication, which is communicating all other steps of this methodology. In other words, this step involves this report entirely.

Having a procedural perspective, this work is going to be fulfilled according to these practices: literature study, software development and experimental test.

3.1 Software Development

When it comes to practical side of this thesis work, implementing a toolkit to support weather-mood researches based on MESM is defined as the main goal. To achieve this goal a system composed of three components has been developed. Figure 5 represents overall perspective of this system.

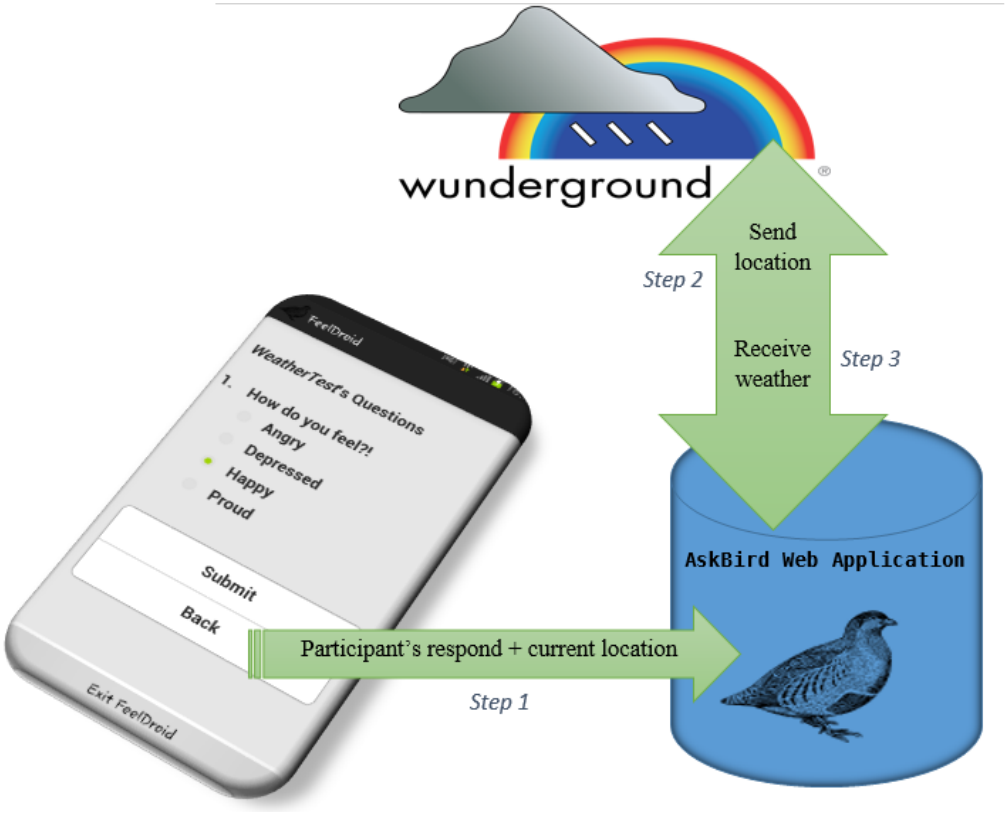

Figure 5: System Overall view

This project can be seen as three subsystems. These subsystems have high cohesion whit themselves and loose coupling with others. High cohesion and low coupling increases level of understandability, reusability, extendibility and maintenance of the system [31]. Subsystems are independent and consequently it is possible to develop, modify and extend them separately. The entire system decomposed into these three subsystems:

1. *AskBird* web application
2. *FeelDroid* mobile application
3. *Wunderground* API

In this section of thesis report functionality, features and relation between these subsystems are presented to the reader.

3.1.1 AskBird Overview

AskBird is a web application which provides different functionalities for participants and researchers. AskBird is the core component of the system. At very first step of designing our toolkit we have reached to this Lo-Fi prototype of AskBird represented in Figure 5 and Figure 6:

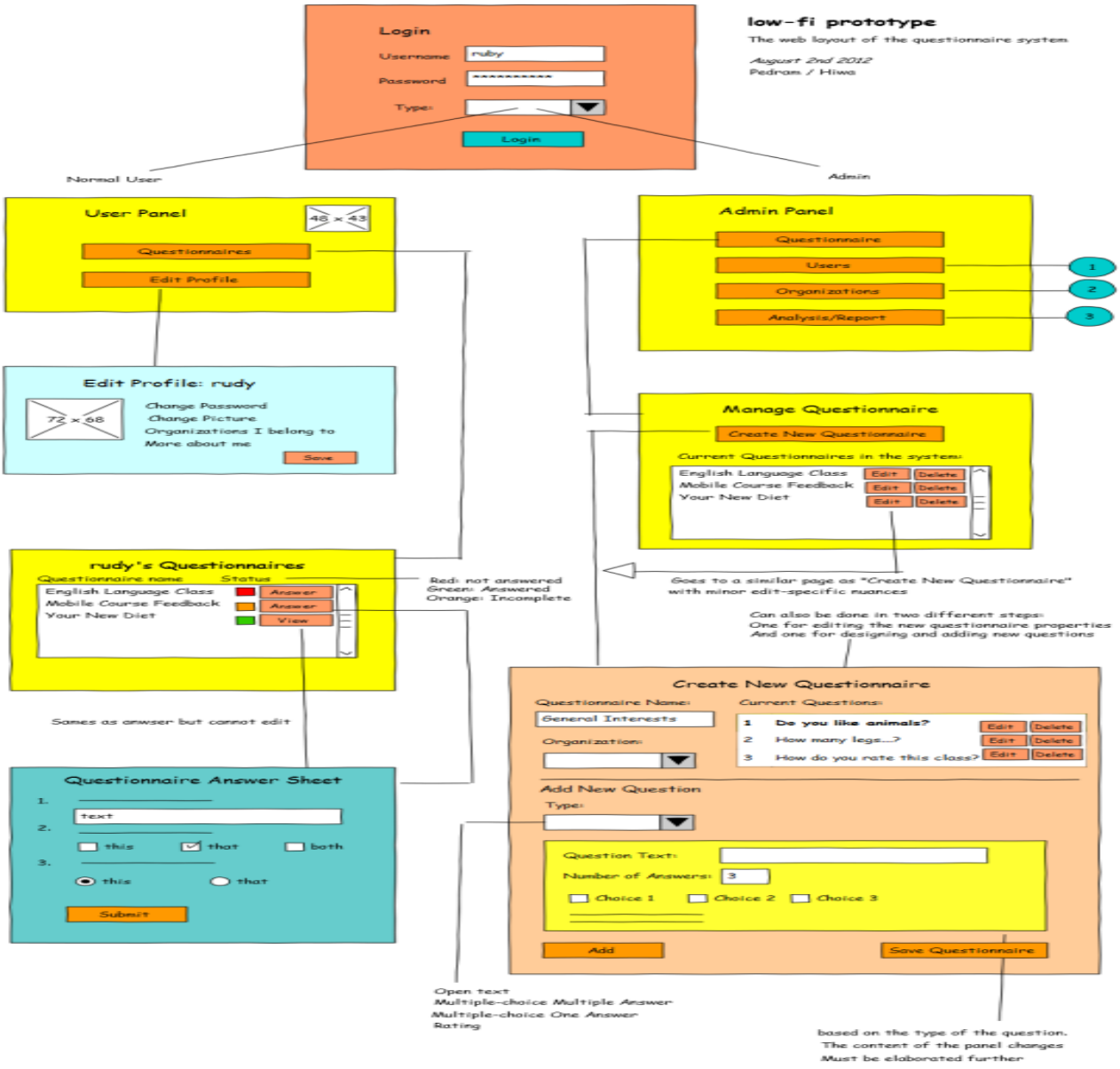

Figure 6: AskBird Lo-Fi Prototype 1/2

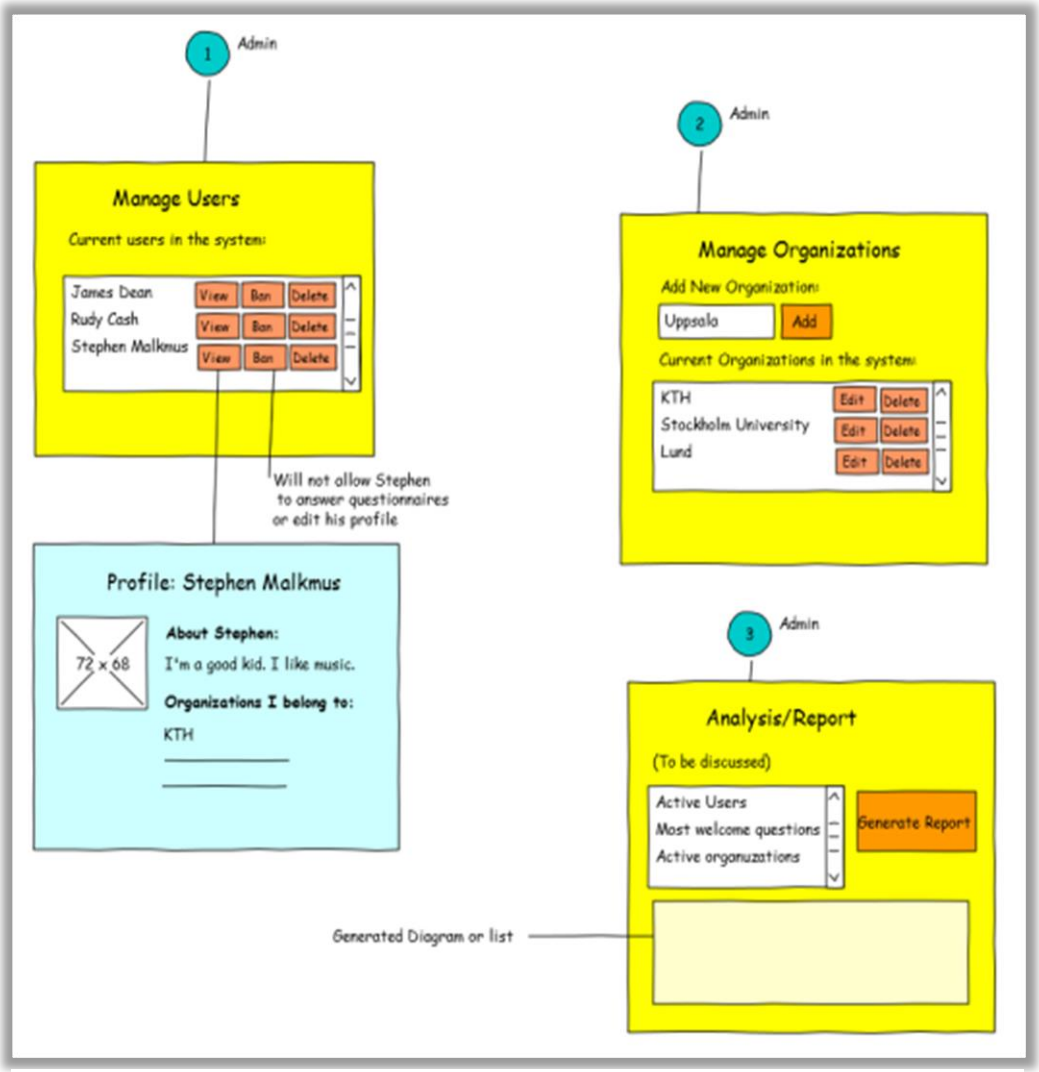

Figure 7: AskBird Lo-Fi Prototype 2/2

Designing and implementing the AskBird web application was a joint work by me and *Pedram Mobedi* [32]. We have started our thesis work together and after developing AskBird toolkit we separated our paths based on our supervisor suggestion. The main purpose of AskBird is to design one time and frequent questionnaires and publish these questionnaires to individuals and groups and finally collect the results to be analyzed by researchers.

As can be seen in the figure 6, researcher should be able to sign in to the system, and then manage participants, groups and questionnaires. Researcher can create new questionnaire, assign this questionnaire to groups and participants. After creating Lo-Fi prototype, system design and analysis started. Figure 8, represented database class diagram generated with MySQL Workbench. Most of UML figures and diagrams designed by StarUML [33]. This diagram was used to implement database tables and java classes.

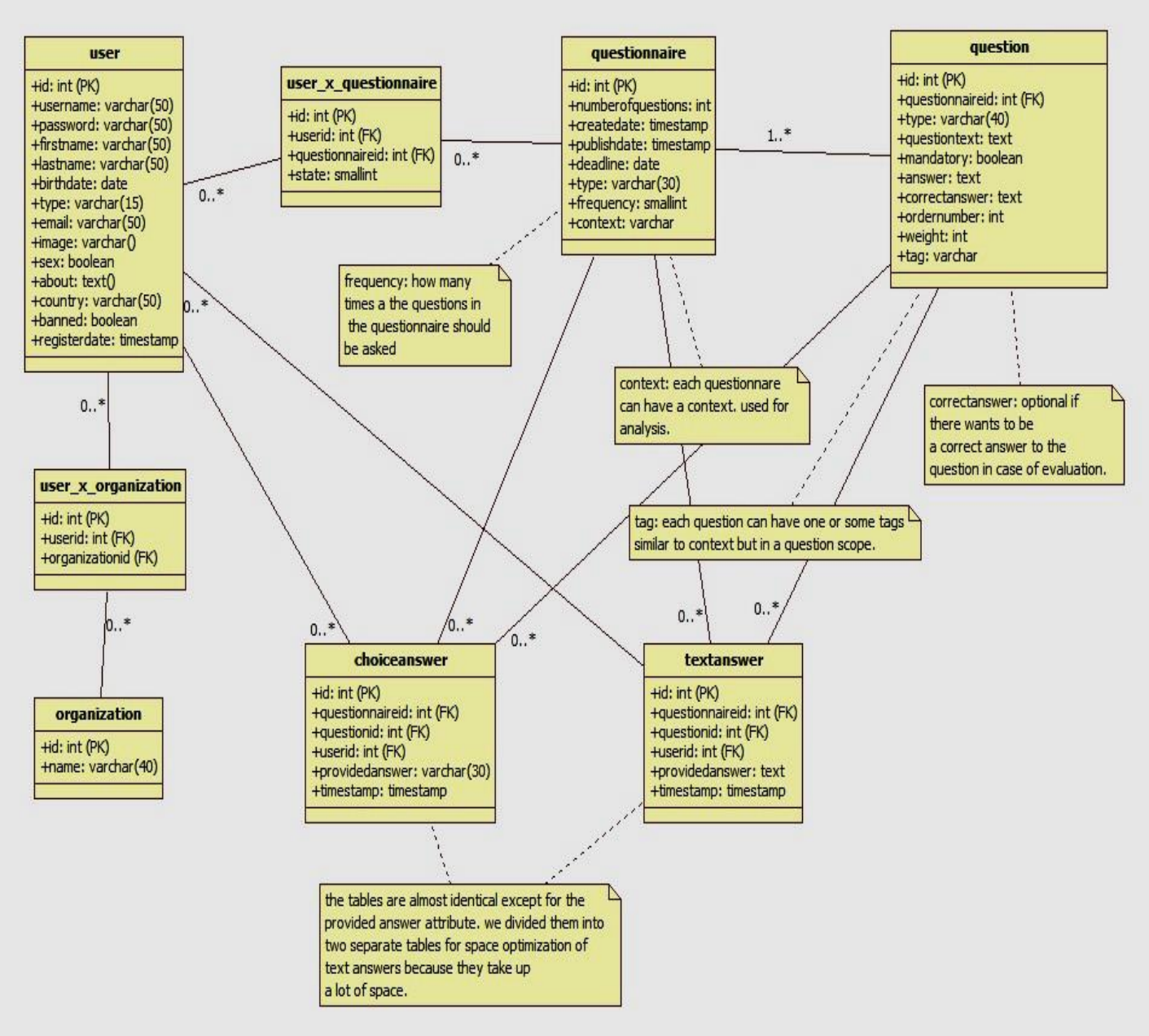

Figure 8: AskBird Class Diagram

AskBird developed in two different GUIs: AskBird *Desktop* mainly supports researchers' functionalities and AskBird *Mobile* which provides functionalities for client (participant) side. *FeelDroid* as a mobile native application uses mobile version of AskBird. Figure 9, represents AskBird Desktop admin panel. All functional requirements needed to run an ESM study like managing forms, users and groups are provided to researcher in this page. In management page, researcher can add, edit or delete related items.

Figure 9: AskBird Admin Panel

Groups:

In order to simplify and better organizing the studies, AskBird supports questionnaire assignment to both individuals and groups. Each group is a collection of users which participate in a specific experiment. According to figure 7, researchers should be able to create organizations. In the real system we changed this name to groups. Researcher can create groups giving them a unique name and assign participants to these groups.

Personalization:

One way to minimize the time and effort needed for participants to respond is through personalization [5]. Personalization can be implemented in different ways for different research purposes. In AskBird each participant has a profile which contains specific information about him like age, gender and so on.

These information make the study more meaningful and enable the researcher to compare the answers efficiently.

Questionnaire types:

Questionnaires in AskBird can be created in two different ways based on frequency. Researcher can design *onetime* or *frequent* questionnaire. A frequent questionnaire might have one or more time interval to be published among participants. Regardless of questionnaire type, researcher should assign a publish date and deadline to each questionnaire. AskBird takes advantages of JQuery as a fast, lightweight and the most popular JavaScript library nowadays [34]. Figure 10 shows a scenario where researcher is creating a frequent questionnaire named *WeatherStudy* and then scheduling publish dates by a JQuery library called *datapicker*.

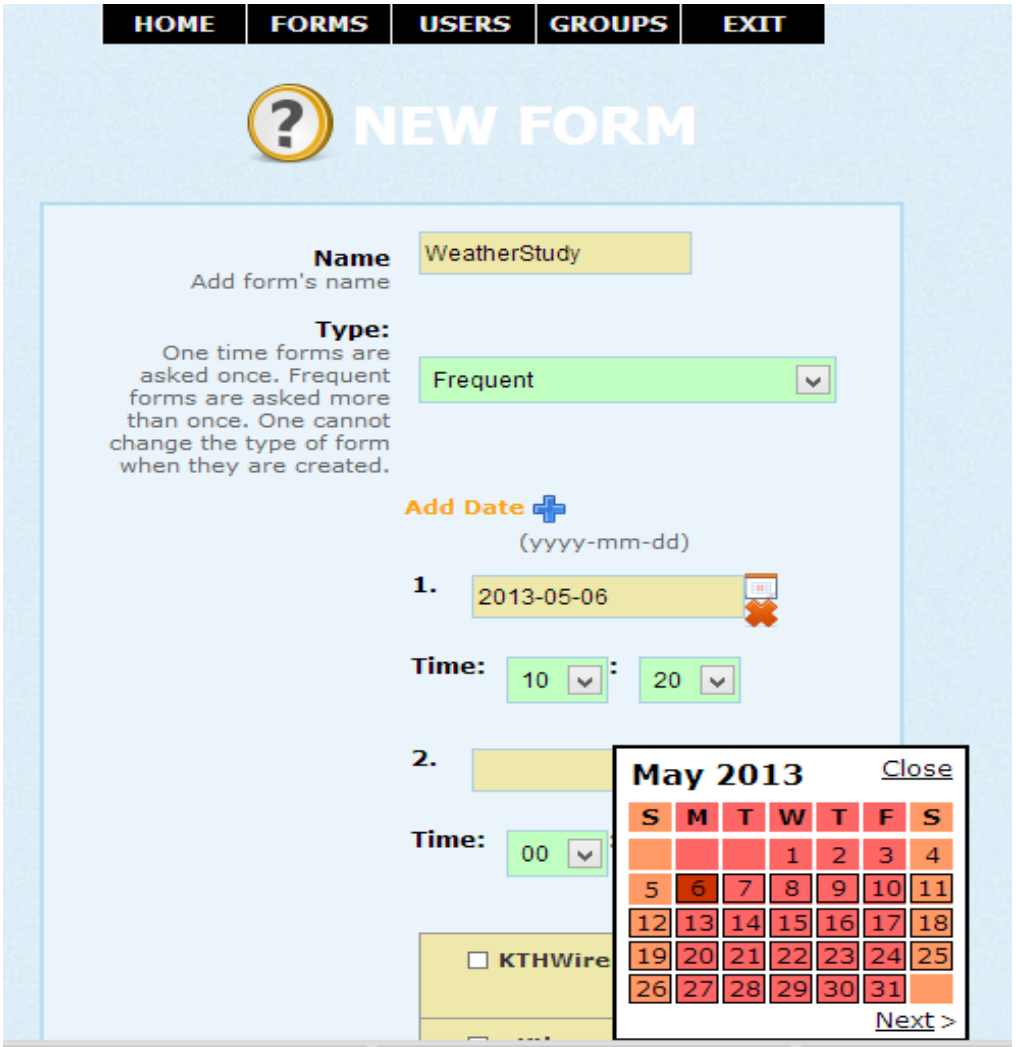

Figure 10: Creating weatherStudy frequent questionnaire in AskBird

Signal and interval contingent:

Notifying participants about publishing new questionnaires is very trivial in running an ESM study. AskBird supports both Signal and Interval contingents (See 2.1.2) by sending email notifications to participants based on researcher scheduling in creating questionnaires. However it was possible to use online notification services like Google Calendar with variety of different notification options [14], we decided to implement notification service ourselves as an outstanding service of an MESM application. Technical details about technologies behind implementing signal and interval contingent will be presented in next step. Due to the limited time for development, only email notification developed, other notification services like SMS notification can be added to AskBird in future works.

Question types:

Questions can be added to a particular questionnaire in 3 different formats. Designing questions is provided for both closed and open questions in order to take advantages of these two methods. Selecting proper method is conceded to researcher [35]. More specifically researcher can create *text response*, *multiple choice with one answer* and *multiple answer* questions [36]. This variety is covering most suitable cases of designing a questionnaire. Selecting question types, adding ad deleting answer items are done at client side by Jquery.

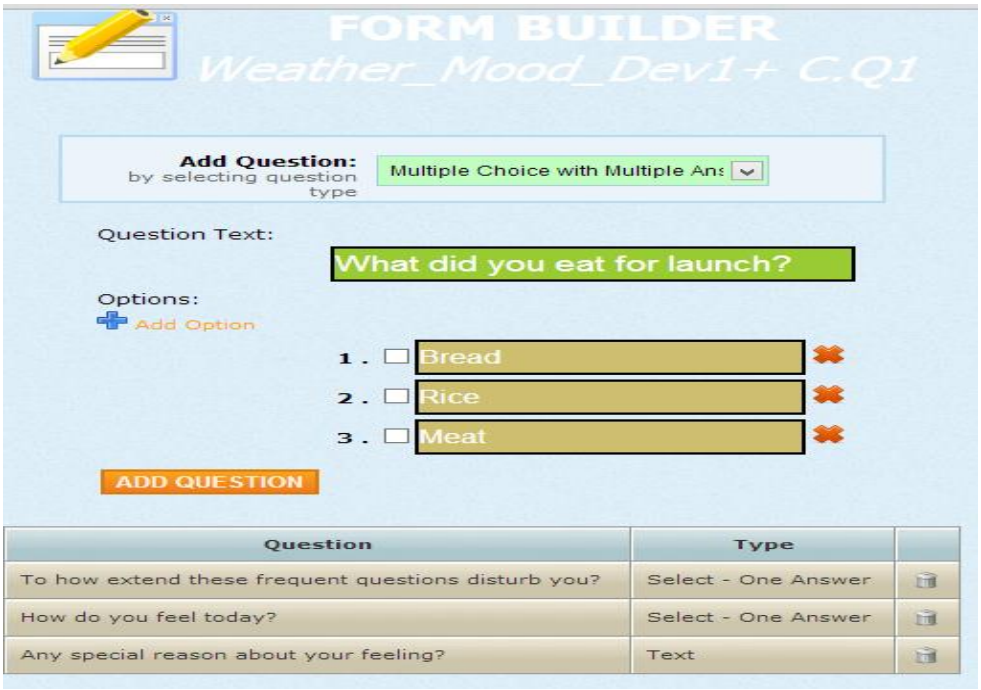

Figure 11: Creating a multiple choice question and add it to the questionnaire list.

3.1.1.1 AskBird Development Tools and Technologies

AskBird as the server side of this MESM application can be considered technically from Frontend and Backend aspects. Considering limited time frame of this thesis project and in order to be more flexible to requirement changes, Agile Software Development practices has been used. XP practice is used in most parts of code implementation by me and Pedram. Reacting more effectively to feedbacks and recommendations of thesis supervisor, an iterative programming approach has been applied [37].

Backend Technologies

Considering the fact that it will be a very long story to describe all tools, techniques and patterns used in this report, here just some remarkable techniques and technologies applied in backend implementation of AskBird will be discussed.

Server Setting:

GlassFish version 3.1 has been applied as the application server for this project. Considering the fact that AskBird is using JSF, JavaBeans and JPA, GlassFish is the most applicable and matching choice since AskBird is purely based on java and matches java platforms and technologies. After software development phase, Glassfish has been installed on one of Ubuntu (version 10.04) servers of KTH. Communication with server machine has been done by a SSH and telnet application called *putty* [38]. Putty lets us to connect to server via a terminal window and run Linux commands on server machine remotely in order to install and modify GlassFish server, and PhpMyAdmin in order to work with MySql database visually.

JSF and Hibernate Frameworks:

AskBird as a web application is written with JSF framework which is the standard Java EE web framework. JSF is a well-designed and easy-to-use component-based web framework which can support implementing MVC architecture. MVC is known as one of the best architectures for developing web applications [39] and JSF can support it entirely.

When it comes to storing results on database, JSF supports ORM. JSF can map database tables automatically to java classes [40]. *Hibernate* framework has been applied as an ORM library to map database tables to java classes. Considering size of the project and providing high level of scalability and flexibility, performance and availability *MySql* has been used as database server [41]. *MySql Workbench 5.2* was used to configure, develop and administrate MySql locally and *PhpMyAdmin* has been used to handle administration of MySql over the web.

Notification Service:

To inform participants about oncoming questionnaires AskBird needs a notification service. To implement notification service, ServletContextListener interface and Timer Task has been used:

```
class NotificationListener implements ServletContextListener {...}

class NotificationTask extends TimerTask{...}
```

ServeletContextListener is like a main() method in a java simple project. Whenever a JSF web application start, context of serveletContextListener start running as well. Inside this interface a TimerTask object created and scheduled for one-time or repeated execution by a Timer:

```
scheduler.scheduleAtFixedRate(notificationTask,0,8, TimeUnit.HOURS);
```

The scheduler, executes notificationTask context every 8 hours. NotificationTask contains the query below, which returns all participants who assigned frequent questionnaires that their publish date passed and their deadline is not passed yet:

```
"select distinct user.* from user,user_x_questionnaire, questionnaire, questionnaire_time where ((user.id = user_x_questionnaire.userid) AND (user_x_questionnaire.questionnaireid = questionnaire.id) AND (questionnaire.publishdate = '" + frequentTimeQuestionnairePublishDate + "') AND (questionnaire.type ='frequent') AND (questionnaire.id = quetionnaire_time.questionnaireid))"
```

Implying Façade pattern and its high level of abstraction, JSF efficiently eases working with database. Façade pattern contains most simple and usable queries, results of queries can be returned as lists and arrays. After receiving results of mentioned query, a notification email will be sent to participants. Javax.mail library has been used in order to set automatic emails to participants. A Gmail account has been used to send notifications with these properties;

```
Properties props = new Properties();

props.put("mail.smtp.auth", "true");

props.put("mail.smtp.starttls.enable", "true");

props.put("mail.smtp.host", "smtp.gmail.com");

props.put("mail.smtp.port", "587");
```

After setting properties of email server smtp and port number, the message properties will be set like this;

```
Message message = new MimeMessage(session);

message.setFrom(new InternetAddress (sender));

message.setRecipients(Message.RecipientType.TO,
```

```
InternetAddress.parse(userEmailAddress));

message.setSubject(questionnaireName + " Questionnaire Notification");

message.setText("Dear” + userFirstName + " " + userLastName + ","

+ "\n\n Please visit” + questionnaireURL + “and answer questionnaire”
+ questionnaireName + "." + "\n\n Best regards \n\n ASKBIRD GROUP");
```

And finally message will be sent to participant;

```
Transport.send (message);
```

Frontend technologies

CSS:

In order to format and design graphical interface of AskBird, CSS has been used as a powerful tool to detail the presentation of web pages such as colors, fonts, and layout. CSS separates document content from document presentation. Besides increasing readability of codes, it would be easier to separate tasks of developers and designers so team members can work independently. CSS makes changeability and modification much easier. By making one change to website's CSS, all pages will be changed automatically [42]. Reusability is another benefit of CSS as a direct result of modular approach of CSS.

JQuery:

AskBird takes advantages of exceptional combination of interactions, effects and utilities provided by JQuery. JQuery has been used in this project in many different ways like scheduling questionnaires, creating questions, form validations, page navigations, working with JSON files and Ajax functions. Using JQuery, we have tried to reduce server load, since JQuery is running on the client side so fewer round trips needed [43]. We found JQuery beneficiary not only in frontend but in backend also. Role of JQuery in communication between mobile client and AskBird Server will be discussed in next sector of this chapter. Like CSS, JQuery offers high level of reusability, changeability, readability, modularity, and task separation compared to custom javascript language.

3.1.2 FeelDroid Overview

On the other hand an Android mobile application called *FeelDroid* is developed and published between participants to interact with AskBird server. FeelDroid is connecting through an Android *Webview* component directly to

AskBird Web application and interact with it. However mobile users can use different browsers to access AskBird web app, FeelDroid besides providing access to the AskBird website provides some more functionalities which are mostly run in the background and hidden from mobile users.

Easy Access and Navigation:

It is possible to temporarily exit FeelDroid and let it stay running in the background by touching Exit button. In this case by retouching application icon, FeelDroid continues to run from its last state. Ability to run the application from last state without need to re-login and extra navigations is a mobile friendly practice which causes increasing quickness in working with mobile app.

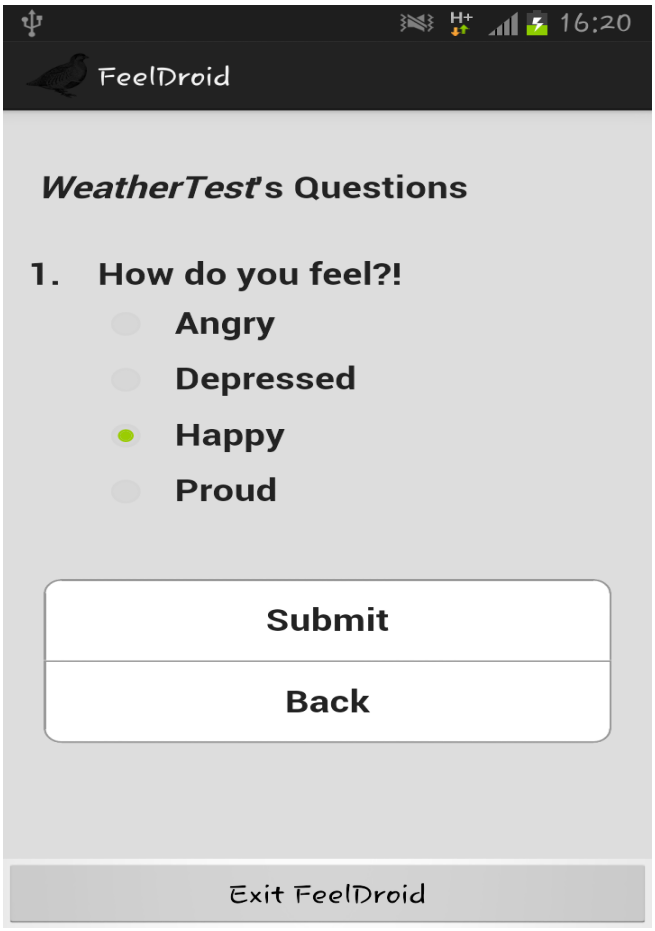

Figure 12: Answering AskBird published questionnaire via FeelDroid

Location Service:

One of the most remarkable aspects of a mobile toolkit to support weather-mood studies is location recognition. FeelDroid is a context aware application which enabled to retrieve location information from both network location

sources such as Wi-Fi and cell towers and GPS. The first step in this case is to declare proper permissions in Android Manifest file. FeelDroid needs 3 permissions to access internet, access approximate location information from Wi-Fi and cell towers and exact location information from GPS [44].

```
<uses-permission
android:name="android.permission.INTERNET" />
    <uses-permission
android:name="android.permission.ACCESS_FINE_LOCATION" >
    </uses-permission>
    <uses-permission
android:name="android.permission.ACCESS_COARSE_LOCATION" >
    </uses-permission>
```

To retrieve mobile location information, LocationListener interface has been used. This Android interface receives notifications from the LocationManager class when the location is changing [45]. LocationManager is an Android class which provides access to the system location services. LocationListener is scheduled to be run in a TimerTask every 20 seconds:

```
LocationTimer.schedule(new GetLastLocation(), 20000);
```

Longitude and latitude result of GetLastLocation() should be transformed into a human readable address containing country, and city of participant. For this reason Geocoder class should be used:

```
Geocoder gcd = new Geocoder(getBaseContext(), Locale.getDefault());
List<Address> addresses;
addresses =
       gcd.getFromLocation(location.getLatitude(),
       location.getLongitude(), 1);
address =
       addresses.get(0).getCountryName()+" "
       +addresses.get(0).getLocality()+ " "
       +addresses.get(0).getAddressLine(0);
```

Now we have the exact address of participant to get weather information in his region. As soon as the participant submits his questionnaire, his retrieved address should be sent to the AskBird server and recorded in the database answer table with participant's answer simultaneously. Satisfying this technical requirement was one of the most challenging tasks of developing FeelDroid.

FeelDroid and AskBird Data Integration:

As discussed before, FeelDroid is connected to the AskBird only through an Android WebView component. In other words, AskBird is totally code independent from FeelDroid. The problem here was to find a way to integrate location information as specific provided information from FeelDroid with participant's answer collectively and insert all of them into database. After some excavation, a fantastic Android method called *addJavascriptInterface()* has been found as the most suitable solution to overcome this problem.

AddJavascriptInterface allows to inject Java objects into a web pages. Injected objects can be accessed by JavaScript in webpage later on [46].

At FeelDroid side, after class instantiation, and binding the class instance to javascript, a name ("AndroidFunction") is given to the JavaScriptInterface method to expose the instance at AskBird side. To give a short notification message to participants after submitting their responses, another JavaScriptInterface called "showToast" has been implemented to show server message on mobile screen after questionnaire submission.

```
final JavaScriptInterface myJavaScriptInterface =
new JavaScriptInterface(this);
Webview.addJavascriptInterface(myJavaScriptInterface,
"AndroidFunction");
...
public class JavaScriptInterface {
              Context mContext;
              JavaScriptInterface(Context c) {
               mContext = c;
           }
           @JavascriptInterface
           public void showToast(String webMessage){

               Toast.makeText(mContext, webMessage,
               Toast.LENGTH_SHORT).show();

           }
           @JavascriptInterface
           public String sendInfoToServer(){
               return address;
           }
    }
```

Now at AskBird side it is possible to call "AndroidFunction" and get mobile location information:

```
<script type="text/javascript">

function GetMobileData() {
 mobileAddress = AndroidFunction.sendInfoToServer();
                                    }

function showToast() {
AndroidFunction.showToast("Experience Recorded. Thanks For Your
Participation.");
}

</script>
```

3.1.3 Wunderground Web Service

According to figure 5, AskBird should be able to achieve immediate weather information as soon as a participant submits a questionnaire respond. There are different APIs and web services to perform this task. Comparing different techniques

and their flexibility in providing different weather information, ease of use and availability of service, *Weather underground (WUndergroud)* has been selected as the most reliable and accurate weather information web service. Weather Underground is the first internet weather service which provides free, real time online weather information to millions of web users [47]. After receiving an API key, it is possible to retrieve data features in JSON or XML within an Ajax function:

```
<script type="text/javascript">

   function getWeatherInfo()

     {

       jQuery(document).ready(function($) {

       $.ajax({

              url:"http://api.wunderground.com/api/bbd176d3c5d75332/ge
              olookup/conditions/q/"+country+"/"+city+".json",
              dataType: "jsonp",

              success: function(parsed_json) {

               maplocation = parsed_json['location']['city'];

               temp_c = parsed_json['current_observation']['temp_c'];

               weather = parsed_json['current_observation']['weather'];

                         }

                    });

          </script>
```

GetweatherInfo() firstly retrieve a message containing both country and city of participant coming from FeelDroid application. Then through an Ajax function, country and city are passed to the wunderground API. After receiving successful response from server, weather condition and temperature are extracted from json message.

Detailed implementation description of this thesis work is finishing here by mentioning this fact that how combining a tiny mobile application like FeelDroid with AskBird, can interestingly add both weather and location awareness to the system.

Chapter 4

Experimental Study

This chapter will represent demonstration of the implemented project reviewed in previous chapter, in a real experiment. As mentioned in previous chapter, this thesis work implies Science Design methodology. By running a real experiment "Demonstration" which is the 4th step of this method will be carried out (See 3).

Through an experiment study, the entire system consists of AskBird as server and FeelDroid as client will be evaluated. Main goal of this experiment and different steps to conduct this experiment will be described in detail. Furthermore results of the experiment and consequently analysis of these results will be presented to the reader.

4.1 Experiment Goals

As it was stated before, This master thesis work investigates current methods and tools in conducting weather-mood studies and tries to bring out an alternative approach to run weather-mood experiments by developing an MESM system. Until now, implemented system, its components, features and functionalities have been detailed to reader. The main goal of this experiment is to evaluate feasibility, performance, easiness and accuracy of this system.

4.2 Experiment Schema

Figure 13 illustrates different steps should be executed in order to carry out the real experiment and achieve experiment goals successfully which are participant recruitment, pilot test, real test and data analysis. More detailed information about each phase will be presented in next pages.

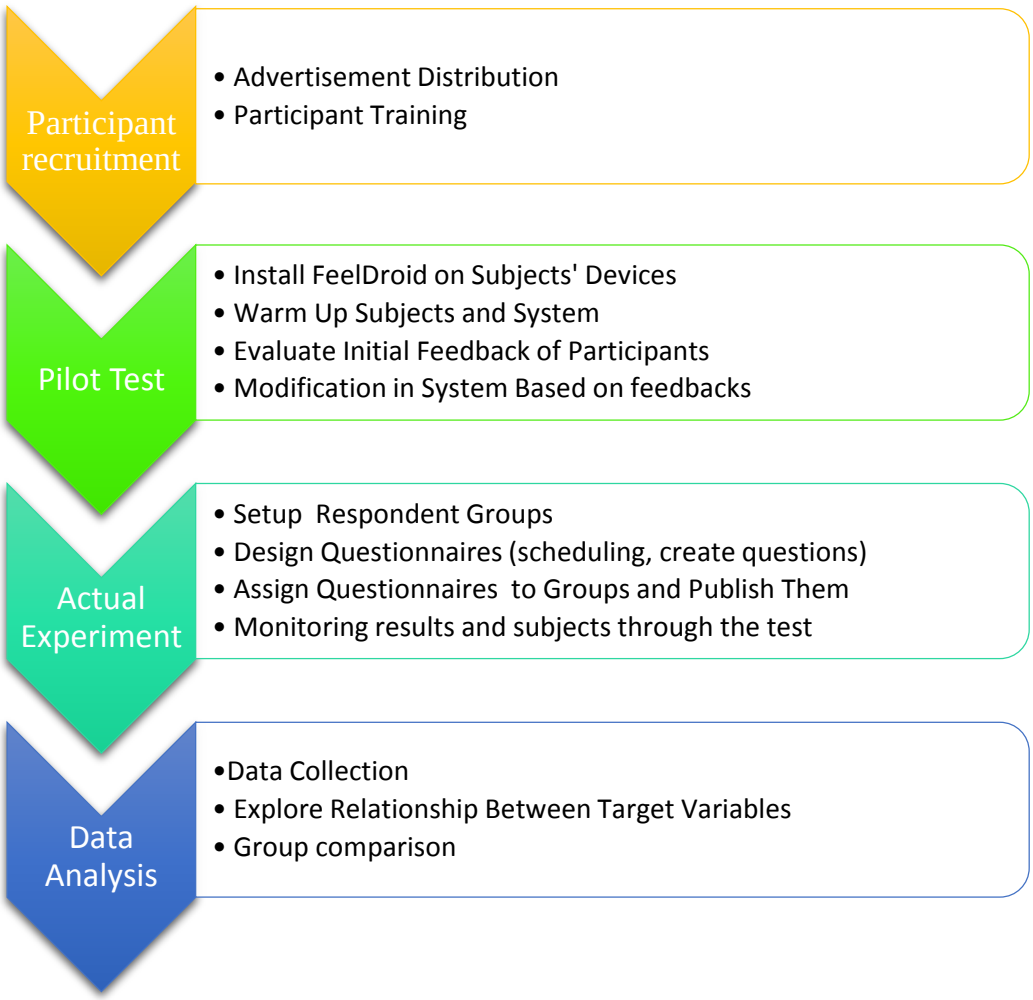

Figure 13: Experiment Schema

4.3 Participant Recruitment

Participant has a unique role in ESM studies. By responding to frequent questionnaires during experiment, ESM puts heavy burden on participants shoulder. Considering the fact that participants should have Android mobile devices, finding active and motivated subjects to participate in the experiment was challenging and tough. Student society is one of the best environments to recruit participants for such experiments [14]. To show potential power of system in running weather-mood studies in distributed and large scales, it was necessary to bring in participants from different weather conditions and consequently different countries. Fortunately by recruitment advertisement in KTH Kista Campus and particularly in Facebook 11 participants from 3 different countries showed interest in participation in the test and have been

recruited. Table 1 represents participant distribution in actual experiment. However this number of participants cannot put on view gainful and considerable statistics to be studied in real world, but it can show ability of system to run this kind of tests in a distributed way.

Table 1: Participation Distribution

Number of Participants	*Country, Region*
7	Sweden, Kista
2	Finland, Tampere
1	Sweden, Vasteras
1	USA, Boston

After finishing recruitment process, subjects registered in the system and provided with a short description about participants' responsibilities and experiment purposes to motivate them effectively. I have tried to clarify participants' tasks by giving them a "readme" file about how to install, run and use the FeelDroid application. After distributing this file and their username and password, participants had 5 days to read this tutorial, install the app and take part in pilot test.

4.3 Pilot Test

Pilot test is one of the essential missions which should be performed before real experiment in order to warm up experiment environment i.e. experiment system and respondents. This sector firstly describes why this work does need pilot test and afterwards the way pilot test conducted will be detailed.

Key reasons to conduct pilot test:

Pilot test can be defined as pre-real test which simulate real test conditions in a small scale of time and budget. More especially pilot test used in order to warm up participants and ensure that they have received adequate training, and instructions so they are able to take part in real experiment. During and after finishing pilot test based on participants feedback and monitoring participants' activity researcher can figure out to how extend respondents have learnt to use the system and what problems they have been faced with. Researcher should react to these problems and feedbacks by training immature participants and modifying the system whenever needed [48].

In our case, pilot test was conducted through answering to a questionnaire. Deadline for submission was 5 days. All the participants answer to this questionnaire successfully. By monitoring the results of pilot test in database this information achieved:

- ✓ All participants have installed FeelDroid successfully on their mobile device.
- ✓ All respondents have sufficient knowledge to use the application and take part in the study.
- ✓ System is able to create questionnaires, publish them based on publish date and deadline, send notification to participants, collect answers plus weather information and inert them into database.

The questionnaire asked participants about their initial experience in working with FeelDroid. By this tricky question besides checking functionality of FeelDroid and AskBird, and ability of subjects in working with system and quality of participation was measured also. Most of participants reported that installing and running the application was easy and without any particular problem.

The only negative feedback received from few participants was about unfriendly user interface of FeelDroid. After checking the situation it was figured out that their device screen is smaller than others. This problem was solved by adding a CSS function to AskBird to automatically set display span based on mobile screen size relatively.

After running the pilot test and warm up the experiment environment, real experiment started for 7 days. Next sector explains real experiment in detail.

4.4 Real Experiment

Running real experiment is one the most sensitive phases of project evaluation. Because it should reflect both power points and pitfalls of the system in running weather-mood researches meaningfully.

4.4.1 Experiment Limitation

There are some limitations in running experiment. For this experiment only 11 volunteers accepted to participate, however, in a real world experiment situation, participant population should be greater to achieve reliable and analyzable results. On the other hand due to limited time of this thesis work it was not possible to run the experiment for a long time. Indeed researches on weather situation need months and seasons to cover all different weather conditions. Due to limitation in time, budget and in order to decrease the burden on respondents shoulder, this experiment was conducted only for 7

days. By mentioning these limitations it is also clear that this thesis work only simulate a real world weather-mood study in small scales of time and population. Finding the relationship between weather and mood is not a goal or even a sub goal of this thesis work.

4.4.2 Experiment Design

The method selected to study the results of experiment is comparison. During experiment participants are behaved differently based on experiment variables and their activity and responses will be compared together. For this reason participants should be divided into groups.

Setting groups:

To satisfy comparison nature of study subject population are divided into two groups namely Group A with 5 members and Group B with 6 members. In Analysis phase behavior of these groups will be discussed and compared. It should be mentioned that ESM intuitively is able to provide within and between participants comparisons (See 1.1). This ability is useful in order to study effects of weather on particular individuals and between individuals.

Frequency:

Important role of frequency was explained previously (See 2.1.2). Typical range of frequency in ESM is between 2 and 12. To set frequency, 3 previous similar researches have been reviewed.

In a research conducted by *Tsutsumi* and others to study effect of humidity on human, 12 Japanese adults were selected as participants and paid for participating in the experiments once a day [28]. In another research to study Contingent Effects of Weather on Mood, 97 data was collected from 97 participants for 70 days with frequency 1 [27]. In the latest reviewed study, 10 students have been selected to rate their moods as accurately as possible four times per day : First after awakening in the morning, secondly before lunch, then before dinner and finally before sleep [25].

Reviewing these researches and considering the fact that our participants are free volunteers, it is not sensible to expect them participate with high frequency rate for instance 8 times a day. High level of frequency is a burden on participants' shoulder which may decrease level of participation and response rate.

Frequency in ESM relies on changes in fluctuating factors of experiment. In clinical researches for instance, where fluctuating factors like heartbeats might changes many times a day, it is reasonable to set the frequency to high numbers. But in our case since the weather condition does not change

considerably along day, it would be enough to set the frequency to one or at most two. To monitor participants' behavior Group A frequency set to 1 and Group B frequency was set to 2.

Questionnaire Structure:

To avoid boringness during experiment, question variation has been considered in designing questionnaires by modifying questions context and ask them in different ways. Open (text) and closed (multiple choice with one answer) questions has been selected in designing questions. Figure 14 represents experiment questionnaires divided into two variations.

Each day during experiment, at first frequency, variation one is asked from both A and B groups at 10 a.m. Deadline to submit responses is 8 hours and after deadline it is not possible to access questionnaire page. At second frequency, questions in variation 2 are asked from Group B only.

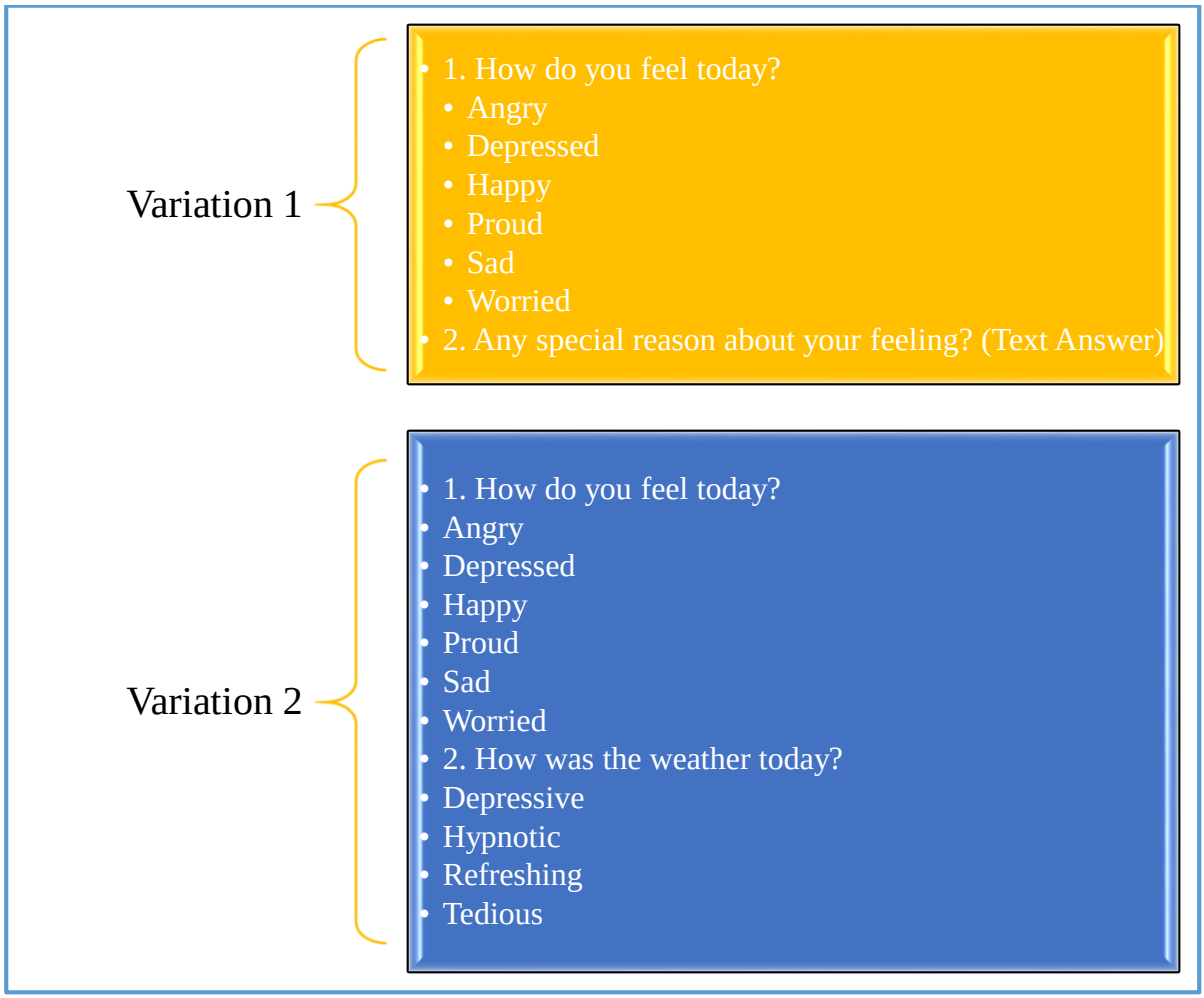

Figure 14: Experiment Questionnaire Variations

Control Questions:

Control questions in this experiment are questions to achieve participants' feedback and experience in using the system. One way to get user experience about an IT product is through face to face interviews or a by send them a list of questions. Since this project is enabled to get user experience, control questions are published through experiment. One benefit to get user experience through the experiment (Not at the end of experiment) is that participants can give their immediate and more reliable feedback about toolkit at the same time they use the application.

Control questions were asked from participants at first, 4th and last day of the experiment. These questions appended to questions in Variation 1 So they have been published for participants in both Group A and Group B.

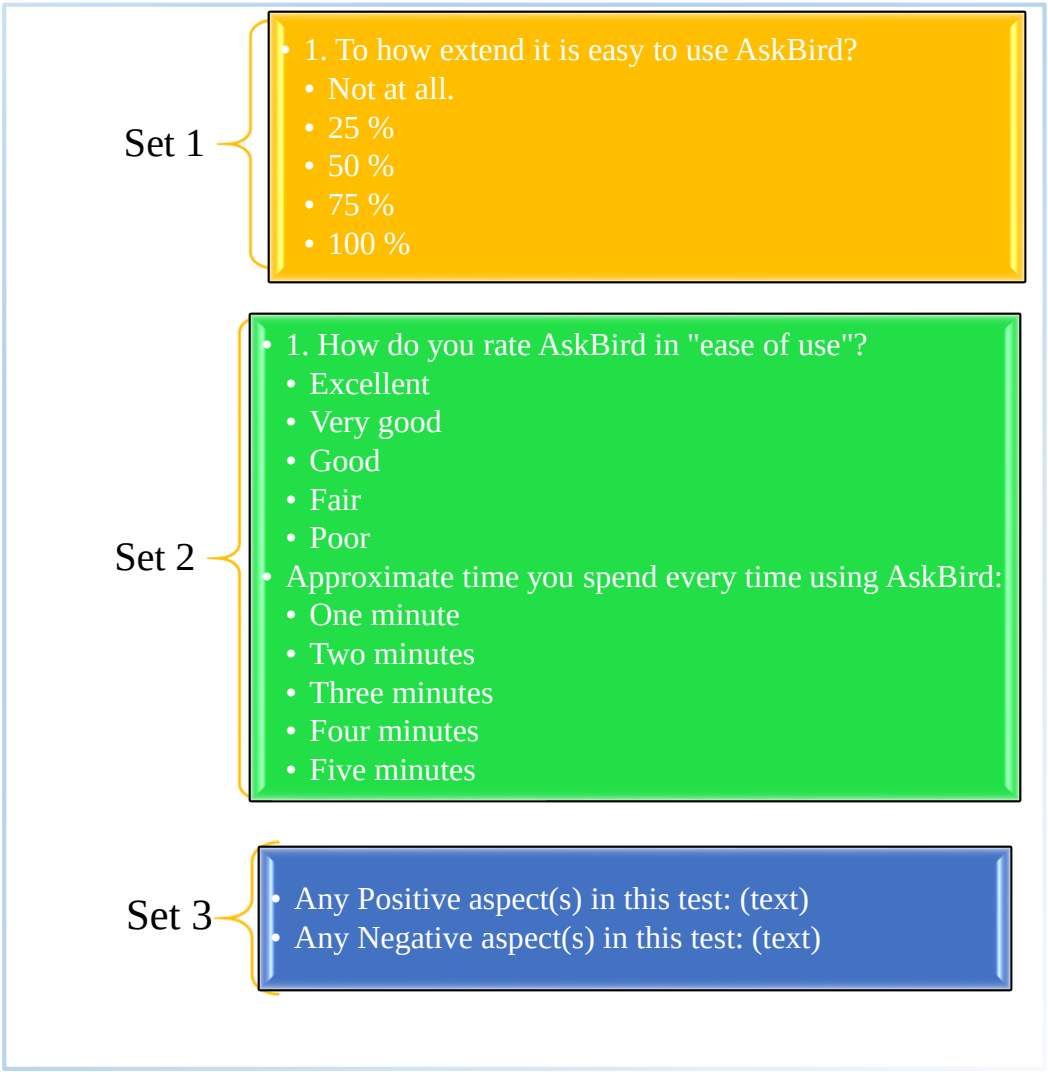

Figure 15: Experiment Control Questions

Chapter 5

Analysis and Evaluation

In order to control the experiment and make sure that it is on the right way, partial data analysis was started from 3rd day of experiment. In this way, it is possible to monitor participants' behavior dynamically and modify study parameters if needed. As soon as experiment ended data analysis started on collected data. Next sector represents analysis on experiment parameters like frequency and question variations mostly based on comparative analysis methodology on two groups of participants.

5.1 User Experience Analysis

In order to evaluate usability of the system, user experience collected and measured based on self-reported metrics such as ease of use and time, ease of learning and so on [49]. This section will bring to light applied methods to measure and score usability of this system. Since this system is a joint work by me and Pedram Mobedi to achieve more information regarding this chapter refer to his report [32].

5.1.1 Participation rate

Importance of participants' activity In ESM discussed before. ESM researches are highly dependent on respondents' activity during experiments. One of the most accurate factors to measure participant's activeness is participation rate. In table 2, second row shows participation rate of group A with average=0.88 (Confidence Interval = ±0.12) and Standard Deviation = 0.15. Third and 4th rows show relatively participation rate of group B separately. As can be seen, respondents in Group B, are more likely to

participate in first frequency with average rate = 0.81 compared to participation in second average rate = 0.71 (Confidence Interval ±0.07). Last row of the table represents average participation of Group B during the experiment.

Table 2: Experiment Participation Rate

Group	Iteration	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	AVG
Group A	1	0.6	1	0.8	0.8	1	1	1	0.88
Group B	1	1	0.83	0.83	0.83	0.67	0.83	0.83	0.83
Group B	2	0.67	0.67	0.67	0.67	0.5	0.67	0.34	0.6
Group B	Avg 1,2	0.83	0.75	0.75	0.75	0.58	0.75	0.58	0.71

When it comes to overall level of participation rate of Group B, statistics observed that it is fairly less than participation rate in group A, in a way that level of participation is almost doubled in Group A in last day of experiment. However there are considerable fluctuation in both trends, according to Figure 16, it is possible to say that frequency has an inverse relation with participation rate. This fact is compatible with previous studies reviewed before (See 2.1.2).

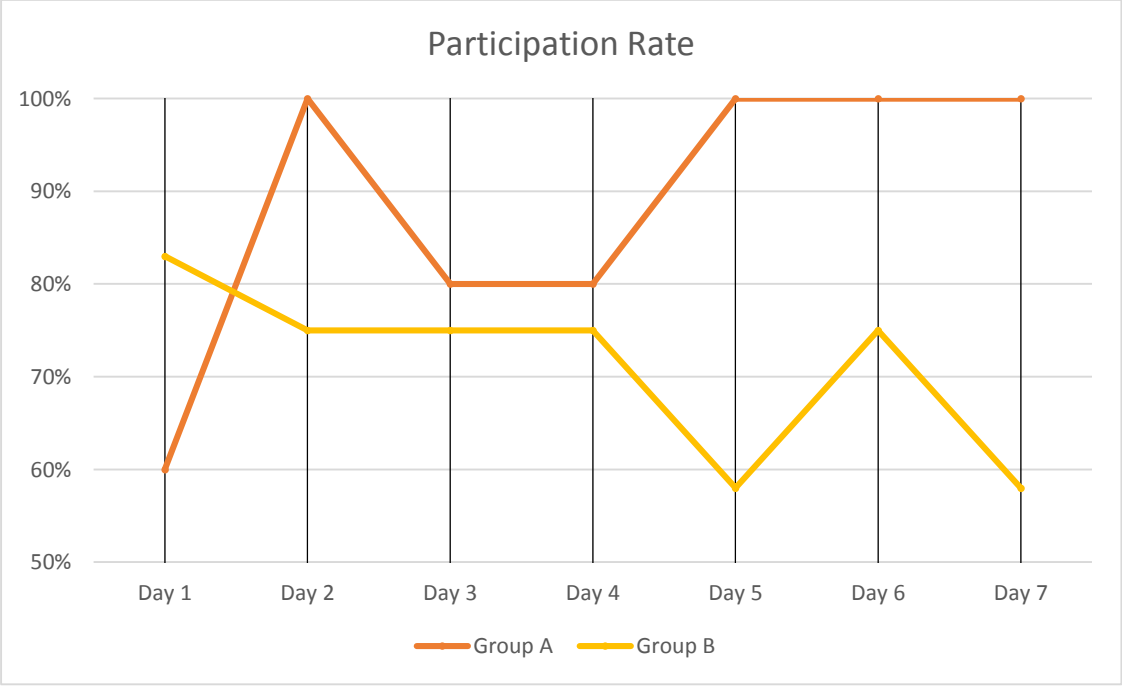

Figure 16: Group A and B Participation Rate comparison

Another interesting finding in studying Group B, is observing behavior of this group itself, based on frequency first and second frequency. According to Figure 17 Group B members are more likely to participate in first frequency compared to second frequency. However both trends fall down gradually along the experiment, in average, level of participation in first frequency is 20% more than second frequency. All in all it is possible to say that participants are more active in earlier frequencies.

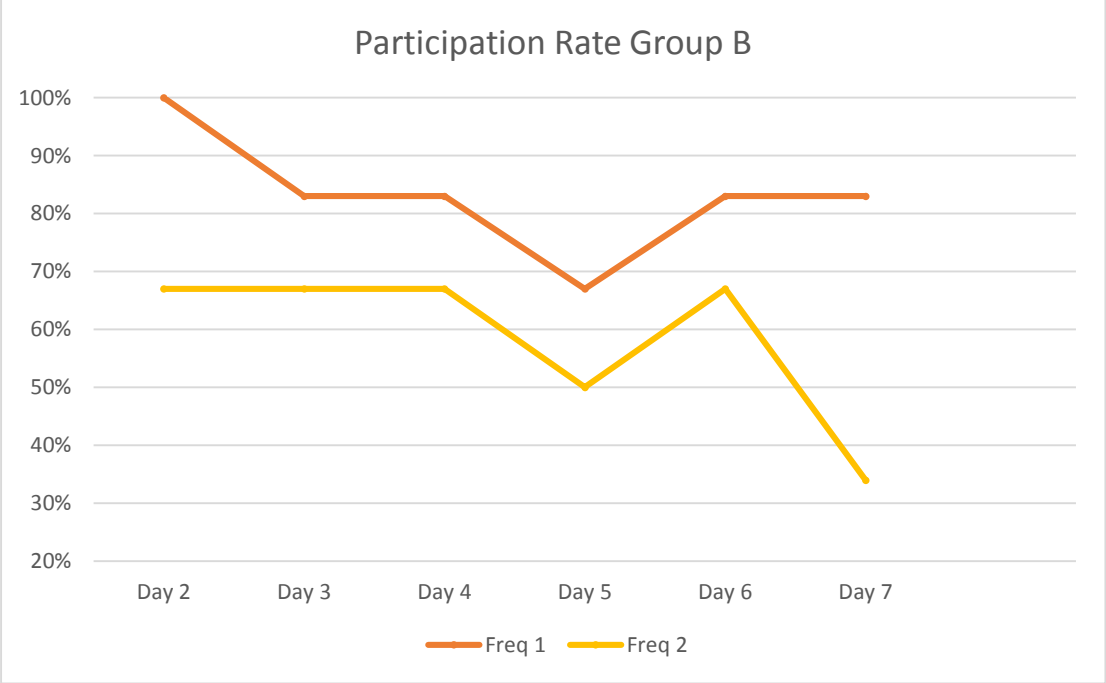

Figure 17 : Participation Rate Group B

All in all, for both groups A and B, participation average rates (Relatively 88% and 71%) are considerably higher compared to some previous similar mood-weather experiments with minimum 11% [50] and maximum 52% [51].

5.1.2 Time on Task

Time on task is one of the most important factors to be considered in an ESM study. Time on task, ease of learning and ease of use are raw usability data factors and new user experience metrics can be derived from these factors [49]. Participant experience regarding this factor was measured by asking participants this multiple answer question during experiment: "Approximate time you spend every time using AskBird". This question was asked in 4th day of experiment along with weather-mood questionnaire. Since this information captured in the middle of experiment, it is more accurate. By asking evaluation

questions along with real experiment question we are more likely to measure user experience more accurately.

9 out of 11 participants answered to this question. Average consumed time is 1.55 minute with ±0.47 confidence interval. According to Figure 18, only one participant spent between two and three minutes in order to answer each questionnaire.

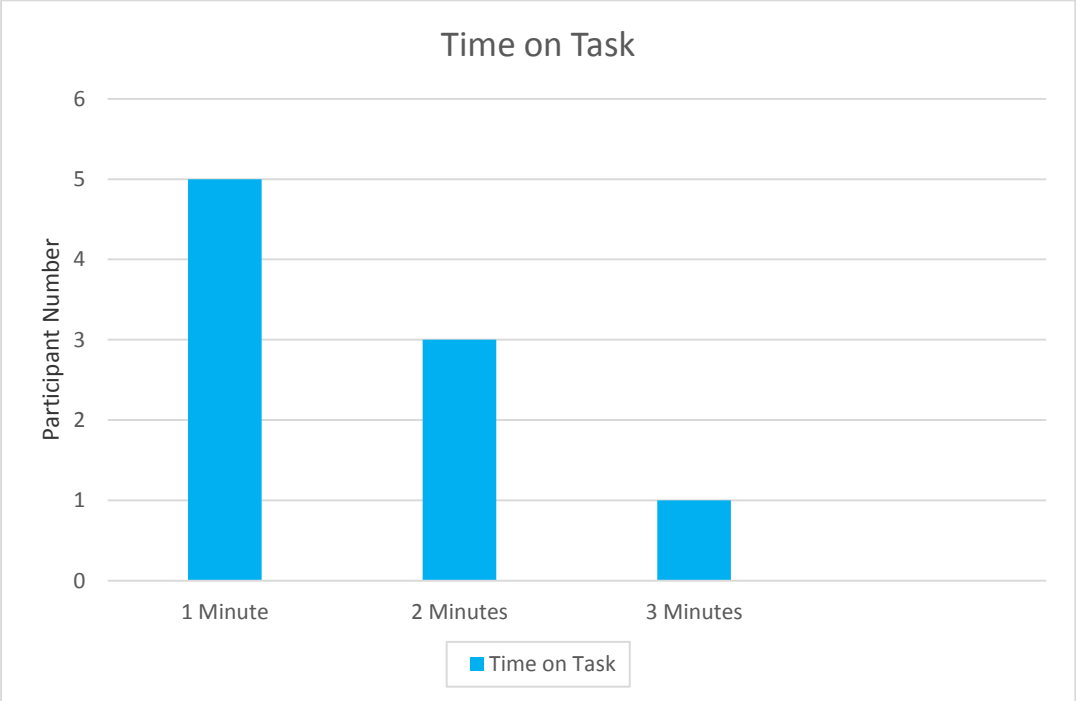

Figure 18: Time on Task

To have more meaningful results and combine these results with other usability data, level of success based on time factors like completion time and time on task, numeric values are assigned to captured data. In this way it is possible to measure success score [49]. Applied policy here is to assign weights for various level of time on task like this:

0<time on task<1 = 1

1<time on task<2 = 0.75

2<time on task<3 = 0.5

3<time on task<4 = 0.25

4<Time on task<5 = 0

According to this weighting policy, the higher percentage means higher level of success. Observed average of time on task is 86% ±0.12.

5.1.3 Level of Disturbance

In prior chapters of this report (See 2.1.3) we discussed that continuous signals and consuming lots of time for participation, irritated participants in ESM studies. Leaving the study by participant is naturally is the most fatal incident in ESM. Therefore one of the most outstanding negative factors to be measured in this system is level of disturbance.

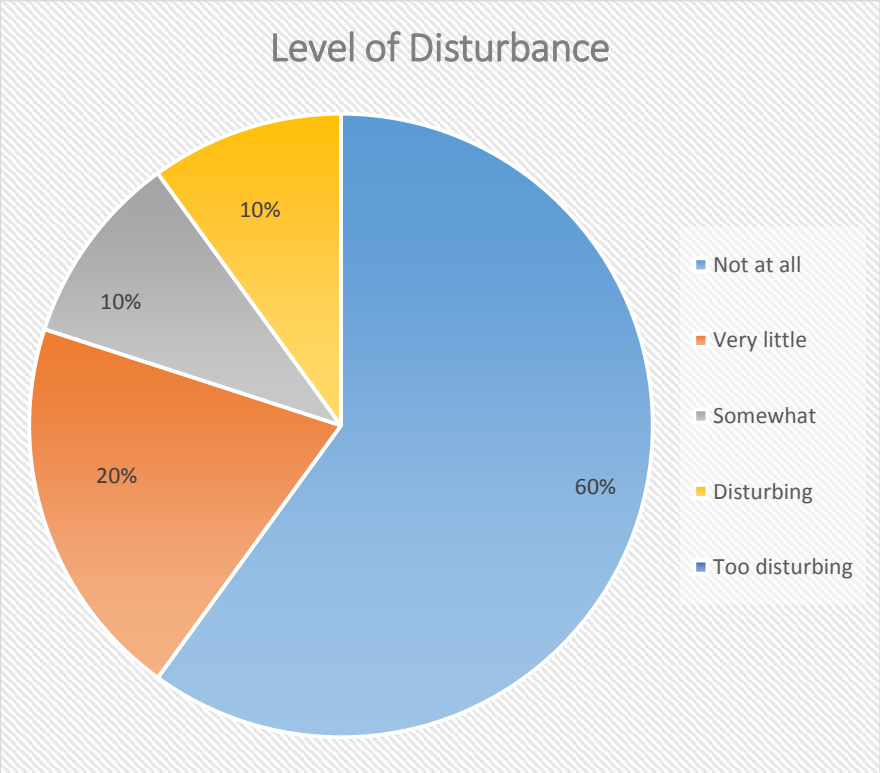

Figure 19: Level of Disturbance

Results in Figure 19, show that interestingly, 62% of respondents did not find the research disturbing at all, and only 10% of participants found this application very disturbing. Like what have been done on previous section, weight assigned to captured data and average level of disturbance calculated 17.5%±0.16.

Role of deadline on questionnaires and low time on task completion are intensively help to achieve this low level of disturbance. Inverse relation of time on task and task disturbance is obvious enough. Implying 8 hours deadline to answer questionnaires decreases natural disturbance of ESM toolkits to a large extend. Participants do not need to response to

questionnaires as soon as they receive signals. On the other hand, since the system is time, location and weather-aware, giving 8 hours to participants does not spoil the results. Researcher does not need to monitor exact response time of participants, since the system itself record time, location and weather at response time.

Furthermore weather and location awareness properties of system, reduces number of asked questions since system can provide correct answers of questions like current weather condition, humidity, temperature and so on.

5.1.4 Ease of Use

Asking users to rate how easy or difficult to use a software to conduct a task is one of the common self-reported metrics [49]. This has been done by asking respondents to rate the toolkit using a 5-point scale as can be seen in Figure 20. 9 out of 11 respondents participate in answering this question and average success score when it comes to ease of use factor is 78%±0.13.

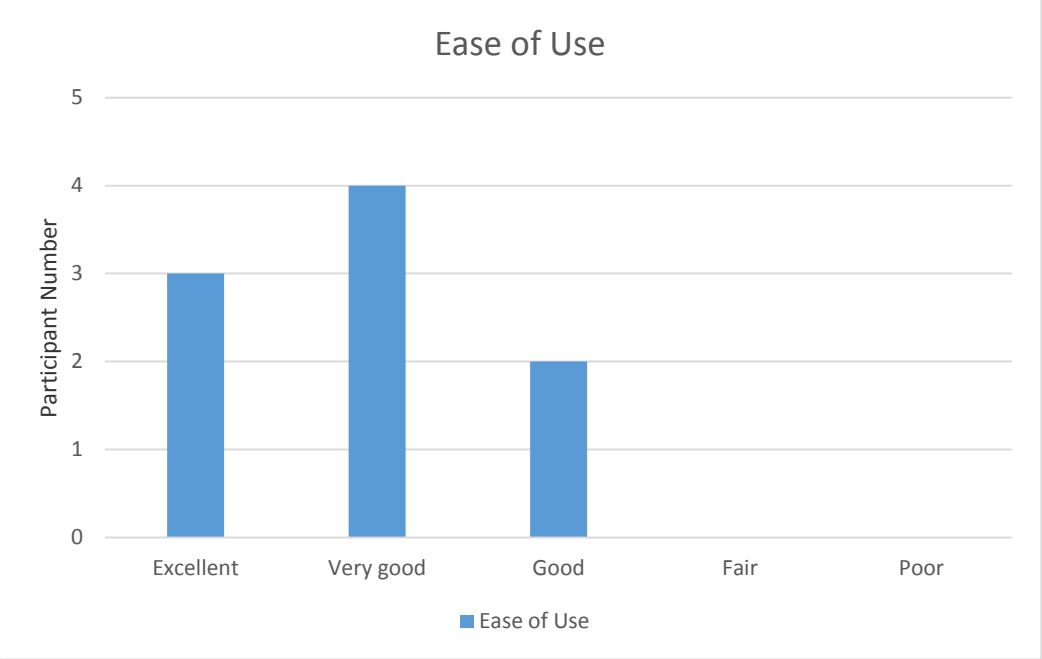

Figure 20: Ease of Use

5.1.5 Ease of Learning

Ease of learning was another factor considered to be measured as a usability factor. 10 out of 11 of participants answered to a question regarding level of ease in learning how to use the AskBird-FeelDroid system. Most of the participants believed that it was very easy to learn how to work with system. Average success score in ease of learning was 81%.

5.1.6 User Experience Radar Chart

Radar Chart is a suitable means to combine and evaluate system usability factors easily. A "useful system" should has "fat" shape for positive factors such as ease of use and "skinny" shape for negative factors like level of disturbance [49].

Figure 21 represents Radar Chart of AskBird-FeelDroid system based on 4 dimensions; Ease of use, ease of learning, level of disturbance and time score. As can be seen in the chart, all positive factors have fat shapes and the only negative dimension of this chart (level of disturbance) is quite short and skinny.

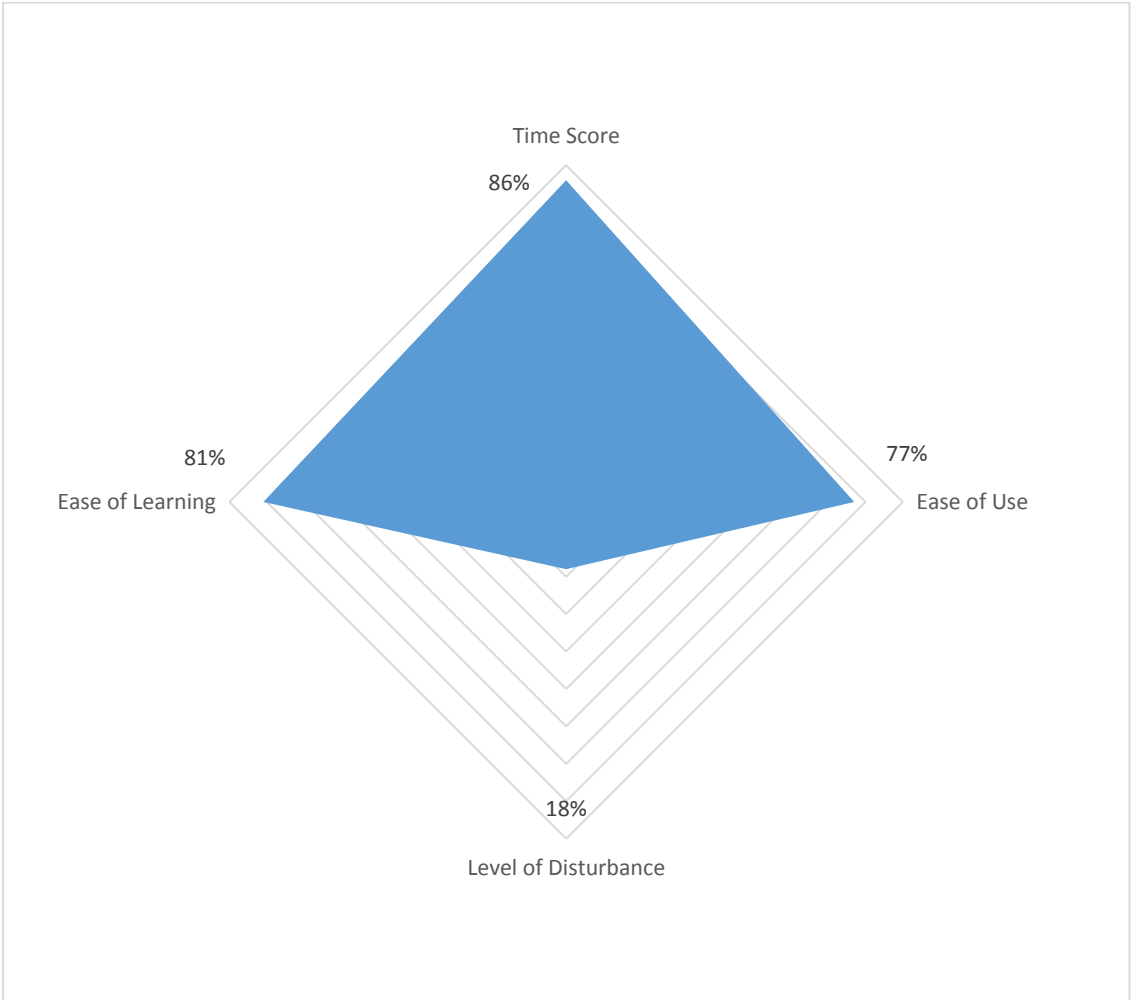

Figure 21: User Experience Summarized Results

5.2 Weather-Mood Data Analysis

This thesis work does not go through finding correlation between weather and mood, but to provide and present a MESM system to support weather-mood researches. In previous sector user experience with this system has been measured and now we are going to show some analysis results calculated based on experiment raw data to see what is the correlation between participants mood and weather condition.

5.2.1 Weather effects on Mood

In Chapter 4 we have discussed limitations in this thesis work, especially when it comes to real experiment (See 4.4.1). So however collected data are accurate and reliable, analysis results cannot be reliable due to these limitations. Furthermore it should be mentioned that obviously there are many different effective parameters besides weather conditions which influence people's mood along time. It is psychologists and weather researchers' responsibility to study and analyze these data. We just show a simple case of comparing weather condition and participants in three mood categories which are "Happy, Worried, and Sad". Table 3 represents captured moods and their correlate weather condition along the experiment. In order to have more meaningful and easy to understand results, it I possible to categorize similar moods [52]:

Category 1: this category consists of positive moods which are happy and proud.

Category 2: this category consists of negative stressful moods which are worried and angry.

Category 3: this category consists of negative depressive moods which are sad and depressed.

Information in Table 3, extracted from MySql database after finishing the experiment entirely. By having some basic knowledge to use SQL syntaxes, researchers can query MySql based on different parameters such as mood, timestamp, location, weather condition, temperature and so on. In this way it would be possible to query same data based on different parameters for different reasons. Each cell of this table represents number of weather-mood correlations captured in first and second frequent questionnaires at each day of experiment.

Table 3: weather-mood correlation data

	Cloudy (Freq1,Freq2)	Sunny (Freq1,Freq2)	Rainy (Freq1,Freq2)
Happy	13,1	17,11	9,2
Proud	2,0	0,1	0,2
Worried	5,1	3,1	4,1
Angry	1,0	0,0	1,0
Depressed	3,0	0,0	2,0
Sad	4,2	2,2	1,1
SUM	32	37	23

Figure 22 reflects relative percentage graph of represented data in Table 3. According to this graph, there is a big difference between participants' positive and negative moods in sunny days. Almost 80% of participants feel happy in sunny weathers however level of happiness among participants, decreases to about 50% in cloudy weather conditions. On the other hand level of depression has been increased from 10% in sunny days to almost 30% in cloudy days. During 7 days of experiment, as can be seen in the graph, respondents felt happier in rainy days compared with cloudy days.

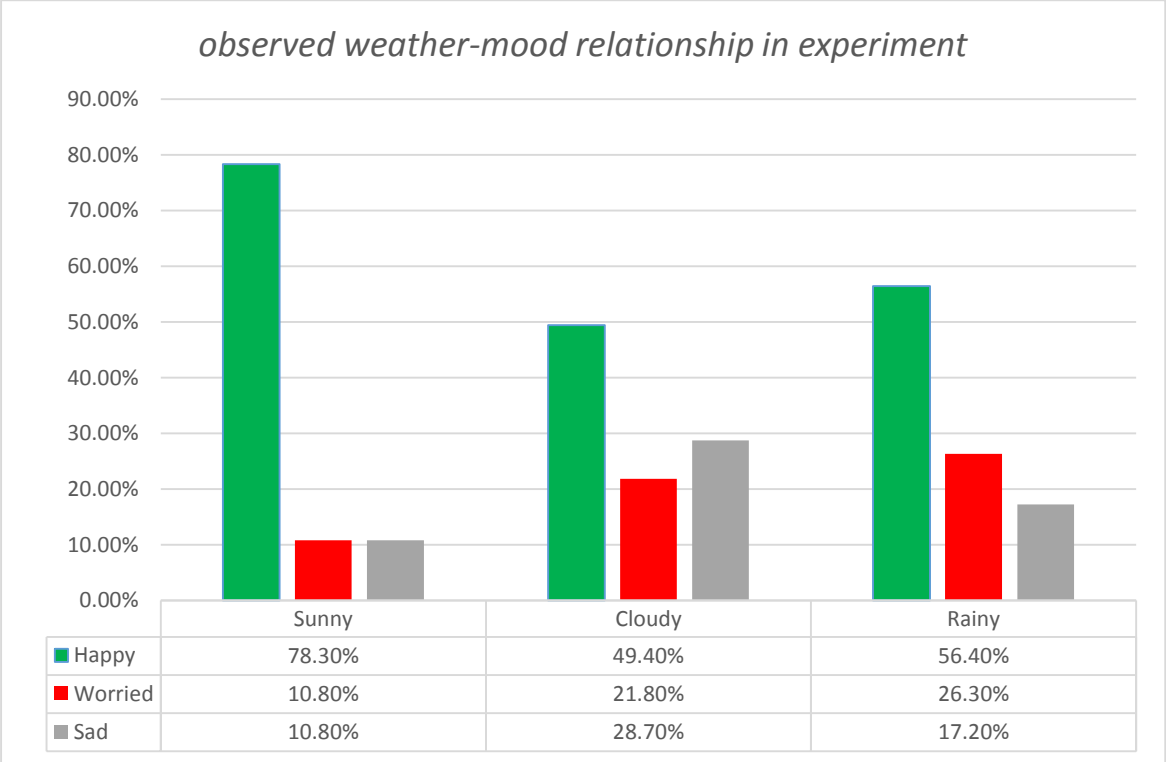

Figure 22: observed weather-mood relationship in real experiment

5.2.2 Non-Weather Factors Effects on Mood

Besides asking respondents to express their current feeling during the experiment through multiple answer questions, participants received a text answer question as well to describe if there is a specific reason for their current mood. Answering to this field was not mandatory. After analyzing the data, participants text answers categorized into 5 main groups (See Figure 23). Four out of 5 factors had negative effects on participants' mood. The only positive factor which bring out positive mood for participants was entertainment.

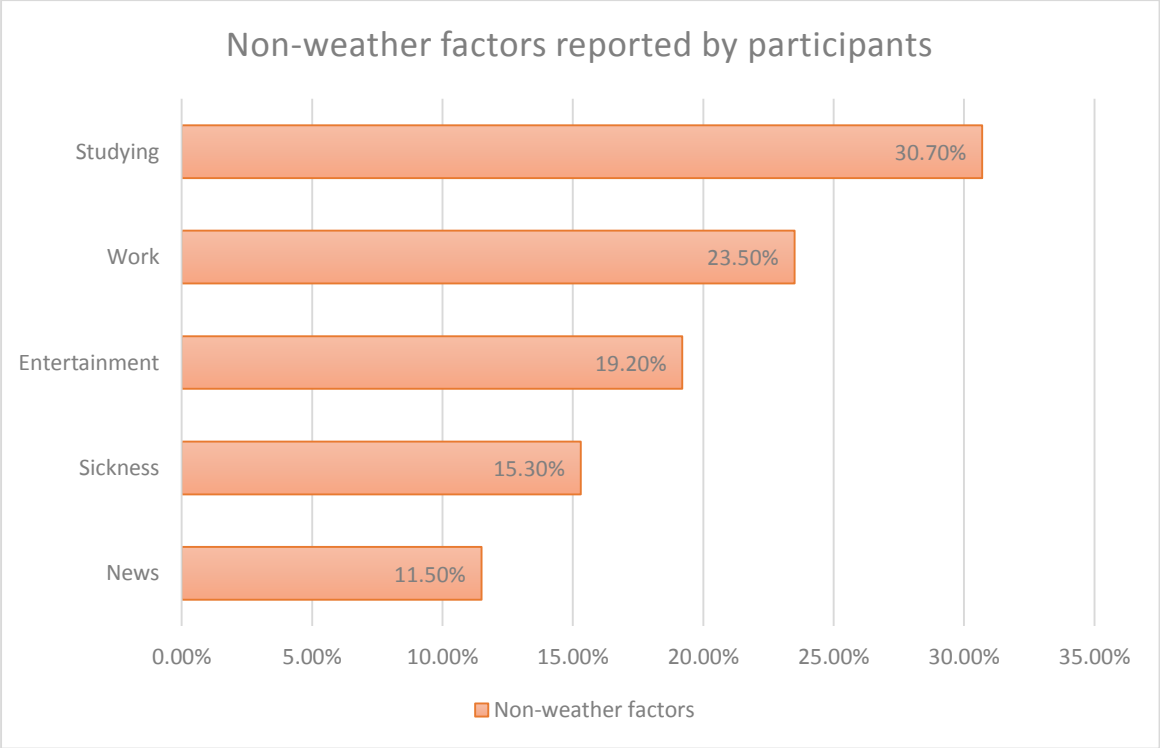

Figure 23: Non-weather factors reported by participants

It was figured out that most of the provided reasons by participants were related to their responsibilities in university or at work. 30% of text answers were reflected students negative feeling about their exams or project deadlines. Studying, work, social and political news, sicknesses and problems in health had bad effect on participants' mood. For instance during the experiment, one of the participants who was living in Boston mentioned Boston bombing [53] and some Iranian participants reported earthquake in Iran [54] as a reason for their sadness or worry. Monitoring collected data from the experiment shows that these factors had more relation with participants' mood. In other words negative effects of these factors on participants' mood are more considerable than good effects of sunny days.

Chapter 6

Conclusion and Future Work

In this chapter, we will firstly state the conclusions reached based upon the work done during this master's thesis project and propose a number of improvements or complements that may be of interest in order to continue this work.

6.1 Conclusion

In accordance with the goals and sub-goals defined in Chapter 1, Section 3 the main research question of this project is if context-awareness specification of mobile technology can positively affects usability of experience sampling experiments. To answer this question, this work aimed to propose and develop a mobile ESM system and evaluate it through a real experiment. In this thesis work, a software system was particularly developed to explore effects of context-awareness in ESM. This system is a combination of an Android mobile application as client and a web application as server.

To run the real experiment, different contexts have been studied to select a proper experiment context and finally weather has been selected. To help answering research question based on proposed experiment, two other sub-questions addressed:

Does context-awareness affect weather-mood researches? To how extend proposed system can improve positive user experience scores such as "ease of use" and decrease negative user experience scores such as "participant disturbance"?

After testing entire functionality of the system and teach participants how to use the system in the pilot test, real experiment was conducted. By dividing participants into 2 groups, participation rate has been measured based on

different frequencies. In this case, analysis of the results from participants in Group A with frequency 1 and Group B with frequency 2, demonstrates that frequency has a direct relation with participation rate and participation rate drops considerably from 88% in Group A to 71% in Group B.

In Analysis chapter user experience regarding AskBird-FeelDroid system has been measured based on different aspects which are time on task, level of disturbance, ease of use and ease of learning. Through studying previous projects done regarding ESM and MESM, their disadvantages and weaknesses have been figured out.

Participant's burden is one of the main challenges in traditional ESM. Analysis experiment results shows that more than 60% of respondents did not find the research disturbing at all, and only 10% of participants found this application very disturbing. Average disturbance level of this system is around 17%. Different reasons might influence to have this low disturbance. One of the factors which affects disturbance level inversely is time on task. In our experiment, average time on task is calculated 1.5 minutes which is comparably low. However we could not find any results about time on task in similar studies in traditional ESM, but for sure time on task in traditional ESM is higher than 1.5 minutes. Here context-awareness plays the mail role again. Context-awareness property of system omitted extra questions about participant's location, participation time and weather condition in participant location. So respondents only need to express their mood, nothing more.

Ease of use of this application has been scored 78% by users. Most of the respondents rated the application ease of use "very good". By receiving a questionnaire notification, it is only enough to open the application and directly visit the questions inside with only two clicks. Via an exit button application is enabled to save the current state of application and restore its state for the next use. Decreasing navigation and high mobile interaction features are considerable keys to increase application ease of use.

This project has answered research questions stated at the beginning of this master thesis. Obviously, all of the presented conclusions were achieved from an experimental study with a small population (11 participants) and in a short time (one week). Considering these limitations this report may not explore all challenging aspects of the study, but it has revealed remarkable issues.

Regarding component-based architecture of this system, it has a high extendibility, changeability and reusability. Applying proper modifications, components of AskBird-FeelDroid system can be modified, improved or reused to solve other problems in ESM domains.

6.2 Future Work

Given the time constraints of this thesis work, AskBird-FeelDroid system supports only some necessary features. Several improvements could be made to the current implementation in order to extend its functionality or applicability in order to transform this system into a viable finished product. There are the high interest topics that could be considered to continue this research:

1. Too much time and commitment impose high burden and low compliance to participants. One applied way in this thesis work to increase compliance is to use mobile technology instead of pen of paper. There are two different other ways to increase participant's compliance, which can be considered to continue this work. Firstly developing a payment schema to motivate participants and secondly developing a feedback subsystem to give partial analysis results feedbacks to participants. In this way participants may gain from participating in experiments by allowing them achieve some information about themselves.

2. Adding some sensors to FeelDroid native application is a way to extend context-awareness power of this project. We have discussed that it is very important for researchers to know whether the subjects participating indoor or outdoor. So one proper sensor in case of weather-mood experiments could be a thermometer to get current temperature of mobile device. Then through a software component it is possible to compare device temperature with weather outdoor to see if the participant is in open areas or in closed areas during experiments.

3. In second chapter of this report some current challenges regarding weather-mood ESM experiments have been reviewed (See 2.4.2) one of these challenges was about running the experiment for a long time in stable weather conditions. Asking same questions when there is not considerable fluctuations in weather condition spoils the experiment. One effective way to face with this problem is through adding a new module to AskBird with the ability to recognize sufficient difference in weather conditions and then signal subjects to participate. In this way AskBird will support event contingent beside signal and interval contingents.

4. During ESM experiments lots of data are produced, which should be analyzed afterwards. In this work, data analysis have been done

manually via MySql queries and Excel software. In a real world situation, researchers may not have enough knowledge or time to work with MySql or other database languages. AskBird does not support analytical functions and there are a lot of work remains to be done here. Through different new functions, achieved data could be exported, and analyzed automatically at least based on formal statistical analysis methods. Furthermore analyzed results could be represented through various dynamic visualizations such as charts and graphs to be more meaningful.

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