WellBee: Mobile Therapy for Stress-related Eating

by

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Abstract

Stress has been shown to affect eating behavior which may lead to eating disorders. Stress may also affect health by causing the modification of behaviors such as physical exercise, smoking, or food choices. Thus, stress-related eating is a problem that many people need help dealing with. As mobile phones have become increasingly popular, a mobile phone application seems like a potential solution and there have already been several studies involving mobile interventions for eating and stress management. This thesis takes such systems further by allowing for continuous, wireless, non-intrusive data collection of EDA, accelerometer, and skin temperature in the user's natural environment correlated with the user's reports of craving and eating incidences while providing affective support when needed via an Android phone. This system uses affect and interruption methods as well as self-report features to collect real time annotations of the user's stress and eating habits. Such a data collection system will eventually allow for a greater understanding of stress patterns that lead to stress eating behavior. Then, the system can provide just-in-time interventions when it detects that the user may lapse into stress eating.

The system has been evaluated in a pilot study with seven subjects who used either the empathetic or non-empathetic system for four days, then used the opposite system for another four days, and finally, were asked to choose which version of the system they would like to use for the last four days. The non-empathetic version of the system was preferred by four of the participants, the empathetic version by two of the participants, and one participant did not notice a difference between the versions so had no preference.

Overall, this thesis has contributed a new system for gathering data to study people's eating habits as correlated with their mood and stress level via an Android phone as well as insight into features that would encourage people to use in situ health monitoring systems.

Thesis Supervisor: Rosalind W. Picard
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I would also like to express my gratitude to the National Institutes of Health (project number 5RC1DA028428-02) who made this project possible with their generous financial support. And thanks to Dr. Amy Ozier who provided me with the EADES questionnaire for use in the pilot study performed for my thesis.

In addition, I would like to thank my academic advisor Professor Patrick Winston for supporting me throughout my five years at MIT on my journey to attain my master's degree. Finally, I would like to thank my family and friends, who have always supported me and encouraged me to pursue my ambitions.

Chapter 1

Introduction

1.1 Eating Disorders and Stress Eating

Stress has been shown to affect eating behavior [8] which may lead to eating disorders. It has been shown that stress may affect health by causing the modification of behaviors such as physical exercise, smoking, or food choices [22]. In a study conducted by Oliver and Wardle [16] , snacking behavior was increased by stress in a majority of the respondents regardless of gender or dieting status. Further, they reported an increased intake of snack-type foods while having a decreased intake of meal-type foods. The foods that were most frequently eaten were sweets and chocolate, cakes and biscuits, and savory snacks while the foods that were least likely to be eaten were fruit and vegetables and meat and fish. As several theories have suggested that eating may provide at least temporary comfort or relief from anxiety for individuals [9, 12], it might be difficult to minimize the number of snacking incidents due to stress. However, if individuals can snack on fruits or vegetables, this would already be one small step toward being healthy when one is stressed.

1.2 Ecological Momentary Assessment (EMA)

Electronic patient questionnaires, also known as Ecological Momentary Assessments (EMA), are generally used to ascertain a person's emotional state in their natural settings, which eliminates the need for recall or patient diaries [23]. EMAs can help increase the respondent's self-awareness. Awareness of one's emotional state can in turn help them modulate their reactions which can impact their mental and physical health [14, 7, 20]. However, the concept of "stress" is difficult to define and the exclusive use of subjective self-report of stress is a weakness of previous studies as individuals may be biased to report answers that they think are more socially acceptable to the answers they wish they really felt [19]. Physiological information can help minimize this bias, since physiological changes can be objectively measured. Thus, the use of physiological information in addition to the subjective measures of stress creates a multidimensional approach to examining an individual's stress and its effects on the individual.

1.3 Cognitive Behavioral Therapy (CBT)

Given the ability to measure a person's mood or stress through the physiological sensors and EMAs, it is possible to provide immediate feedback to individuals which can help keep them with stress or anxiety management.

Cognitive behavioral therapy (CBT) is a standard procedure for treating many mental health disorders such as addictions or anxiety. The therapy consists of techniques for self reflection as well as techniques for coping with episodes of craving or stress. Examples include relaxation techniques (e.g. breathing exercises) or imagery (Imagine yourself on a beach).

Cognitive behavioral therapy is considered the treatment of choice for eating disorders such as bulimia nervosa [6]. The use of CBT combined with physiological

monitoring has only recently been demonstrated making use of the decrease in heart rate variability (HRV) as a measure of patient stress [13].

1.4 Mobile Phones

With recent advances in mobile phone processor speeds and open software development tools coupled with the phone's portability, the phone seems to be a very attractive tool for the delivery of EMA and CBT. The mobile phone has many advantages including instantaneous recording of data, date and time stamping of data, and easy integration into one's daily life [18]. EMA and CBT are both well-suited for deployment on mobile phones [2, 14]. Mobile phones can introduce prompts at random intervals which will reduce reporting and recall biases [2]. The increased processor speeds, memory capacity, and the ability to interface with other hardware of recently developed phones allow for continuous sensor monitoring and data collection as well as facilitate interactive feedback [18]. Continuous physiological monitoring and EMA can work together to provide just-in-time CBT as needed by the users.

Chapter 2

Background: Mobile Interventions for Overeating and Stress Management

As mobile phones have become increasingly popular, there have been several studies involving mobile interventions for eating and stress management. A few of these are outlined as follows.

2.1 Mobile Therapy for Bulimia Nervosa

One of the earlier studies performed by Shapiro and others involved in the use of text messaging to continue delivering CBT to women with bulimia nervosa for the 12 week period during which they had participated in 12 weekly group CBT sessions as well as the 12 week period following these sessions [21]. Each night, the participants would submit a text message indicating the number of binge eating episodes, purging episodes, peak urge to engage in binge, and peak urge to engage in purge (Likert scale of 0-8). Based on their answers, they received a feedback message such as "Good job with resisting your strong urge to purge today. Try harder not to give into the binge

eating tomorrow. Call a friend instead.". Feedback messages corresponded to how well they had done that day in meeting the goal of abstinence from binge eating and purging as well as how well they had done in meeting their goal relative to the previous day. Participants of this study adhered to the daily self-monitoring with a rate of 87%. Based on the information that participants submitted via the text messages, the number of binges, number of purges, peak urge to binge, and peak urge to purge reported during the first week of self-monitoring and during the last week of self-monitoring were calculated. Shapiro and his team found that the mean number of purges significantly reduced from the first week of monitoring to the last week of monitoring. Thus, this system of delivering immediate CBT via a mobile phone based on participant's responses to an EMA was shown to be effective. In fact, two participants asked if they could continue to use the program even after the study ended as it helped them with their recovery. In my study, I develop this system further by bypassing the need for the exchange of text messages. This provides the added benefit that a participant does not have to have reception or even a service plan on their phone to receive CBT when they need it.

2.2 Mobile Therapy for Monitoring Real Time Caloric Balance

Tsai [24] and his team developed PmEB, a mobile application that allows users to monitor their caloric balance throughout the day. They simply reported whenever they ate or performed any physical activity. This information would be uploaded to a server that will keep track of the user's caloric balance for the day. At the end of the day, users can check their caloric balance which is accompanied by a short encouraging messages such as "Good job! You are exceeding your goal by 1000 calories!". A comparison of three groups of users was studied: one group used

paper caloric tracking forms, one group used PmEB where they received one text message reminder per day to report their caloric intake and expenditure, and one group used PmEB but received three text message reminders a day. The study began with fifteen participants, five in each group. Four participants completed the study for paper group, while five participants completed the study for each of the other groups. Each participant used their particular caloric tracking device for a month. A post-study survey was given to assess the caloric tracking methods for their usability and feasibility by asking questions such as how disruptive the device had been, or whether it changed eating habits, etc.. Answers were given on a 1-5 Likert scale. Based on the answers to the survey, although all three caloric tracking systems were easy to understand and use as well as motivating, the one-prompt version of PmEB had the most positive review from the users. It seemed to be the least disruptive and frustrating, while having the greatest impact on changing the activity or eating habits of the individuals. All five of the participants of the one-prompt version of PmEB reported that the device helped change their eating or activity habits and that it impacted their awareness of their eating and activity habits. Further, those using the mobile application felt that their information was more private even though they were not aware of the security measures available. This may be another reason to use mobile phones for eating management systems since users may trust the application more if they feel their information is private.

2.3 Mobile System for Understanding Stress and Interruptions

Mobile interventions for overeating or eating disorders may cause the user increased stress if the mobile phone interrupts the user too many times a day. Although the mobile phone software could simply limit the number of interruptions, the more times

we can get feedback from the user, the better our understanding of the user's eating habits will be. This will allow us to developer a mobile system that better helps users conquer their eating temptations and eating disorders. Liu's master thesis work [11] has discovered that users are more willing to keep using the responsive mobile phone system. The responsive system responds to the user's feedback with empathy and appreciation for them taking the time to fill out surveys at randomly prompted times. This technique has been incorporated into my WellBee system so users will be more likely to provide continuous feedback which will be beneficial for the development of the system.

Chapter 3

System Overview

The goal of the WellBee system is to help participants eat healthy even when they are stressed by encouraging them through CBT to eat fruits and vegetables and to find another way to reduce stress when participants are tempted to eat. As mentioned in 1, when individuals are stressed, they tend to eat more unhealthy foods while eating less healthy foods. Thus, by encouraging participants to eat healthy foods when they are stressed, perhaps, we can prevent or lessen the decrease in their intake of healthy foods. This might in turn result in a decrease in their intake of unhealthy food compared to when they are normally stressed. WellBee contains three subsystems: a sensor band, an application to collect data on an Android mobile device, and a server to configure settings on the Android application and to store collected data.

Figure 3-1 shows the overall architecture for the WellBee system.

3.1 System Design

The WellBee system was based on another system, iHeal, which was used to provide CBT to drug addicts and prevent them from relapsing into drug use [4]. The iHeal system was developed by a team, which I was part of. I helped develop the phone software as well as the PC Application which are detailed below. I adapted the com-

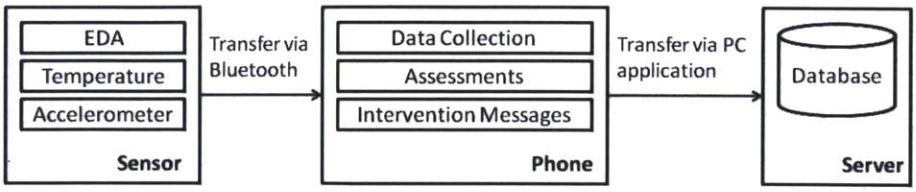


Figure 3-1: This diagram shows the WellBee system's overall architecture.

Figure 3-2: This diagram shows the sensor band mounted on a person's ankle.

ponents of iHeal for use in WellBee. The following sections describe the components of the system in further detail.

3.1.1 Sensor Hardware

The sensors developed for WellBee continuously measure skin conductance (EDA), skin temperature, and 3-axis accelerometer values [5]. These values are recorded on an SD card attached to the sensor band as well as transmitted to the phone via Bluetooth. A photograph of a sensor band mounted on a person's ankle can be seen in Figure 3-2.

3.1.2 Phone Software

The WellBee phone software was implemented for the Android OS and can run on phones with Android version 2.0 and higher. For my study, the software was developed

specifically for the Motorola Defy phones which are currently running Android version 2.1 update 1.

Software Architecture

The multi-threaded WellBee application consists of several components: 1) Data Collection, 2) EMA surveys (Assessments), and 3) Intervention Messages. The Data Collection component runs in the background to receive the sensor data via Bluetooth and applies a decision algorithm on the values to determine if the user might be feeling stressed and in turn tempted to eat. If this condition is detected, the application then triggers the EMA component (assessments), and based on the participant's responses to the questions, displays an appropriate intervention message. An intervention message consists of a text message paired with an image. All interaction is also time-stamped and recorded to a file. The data on the phone was organized into multiple folders: physiology sensor data, assessment data (participant's responses to the questions), custom intervention content (images and intervention messages), and decision algorithm parameters (described below). Although the ability for participants to insert their own custom images or intervention messages into the phone application is built into the system, this functionality was not used in the study pertaining to this thesis. But this feature may prove to be useful for future uses of the WellBee system.

Interaction Design

As shown in Figure 3-3, WellBee supports four separate modes of participant interaction:

1) Self-reported Eating Temptation or Stress: The user can report when they are tempted to eat or when they are feeling stressed or in a bad mood. To do this, they press the "Report Craving or Feeling" button on the Home Screen shown in Figure

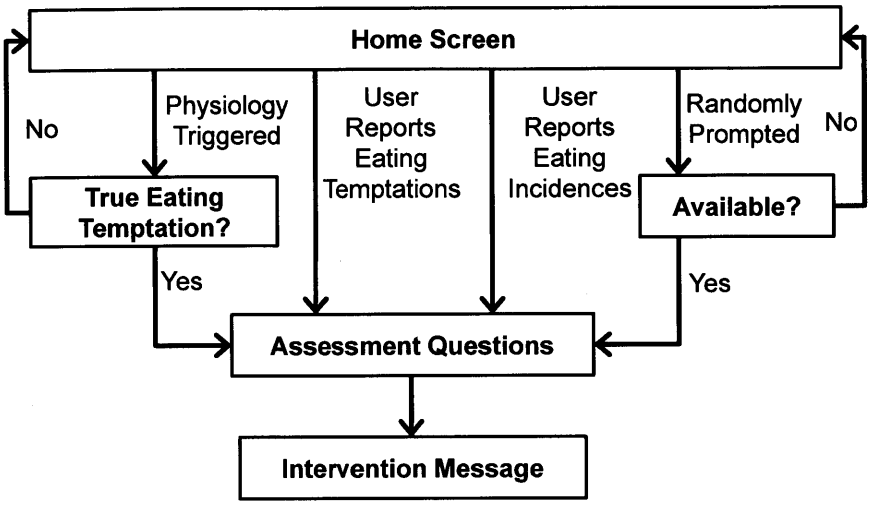


Figure 3-3: This diagram shows the different ways participants can interact with the WellBee phone application.

3-4. The user is then asked to answer a short EMA survey as described in 3.1.2 which will be followed by an appropriate therapeutic and empathetic intervention message.

2) Self-reported Eating Incident: The user can also report when they do eat by pressing the Report Eating button on the Home Screen shown in Figure 3-4. The user is then asked if they ate something that helped accomplish their goal of eating five fruits and vegetables a day (Figure 3-5. If they answer that they ate a fruit or vegetable, the phone will display a message of praise such as "Good job!" along with an appropriate image. However, if they answer that they did not eat a fruit or vegetable, they will get a message reminding them to work on eating healthier the next time they want to eat something, such as "Oh no! You didn't meet you goal this time. Refocus on your goal. I know it's hard, but every achievement begins with trying." Figure 3-6 shows another such sample response.

3) Physiology-based Interaction: If the phone detects an unusual arousal event,

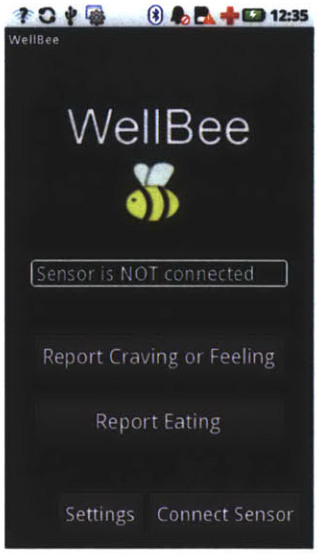


Figure 3-4: This diagram shows the WellBee application Home Screen.

then the phone will alert the user with a screen message along with optional vibration and/or sound alert. The exact physiology signature that triggers the intervention is defined by algorithmic parameters (such as rise time, slope and magnitude combinations) that are stored in the "algorithm" folder of the directory storing all of the user's data on the phone. The parameters will vary for individuals, so the system supports individualized settings that are customized to each patient's physiology and degree of reactivity.

In order to address inevitable false positives, the phone first displays a verification message "How are you doing?" If the user answers "Good" then the system goes back to its default state. But if the user answers "Bad" then the phone proceeds to ask the user the EMA questions regarding how strongly they are tempted to eat, their mood, etc.. The EMA questions are discussed in more detail in Section 3.1.2 below. This is followed by a therapeutic and empathetic message. If the user ignores the "How are you doing?" message, or cannot attend to the phone (e.g. busy or driving) then the message will automatically disappear after 30 seconds. The user is also given the ability to turn ON/OFF the phone sound and/or vibration for these alerts.

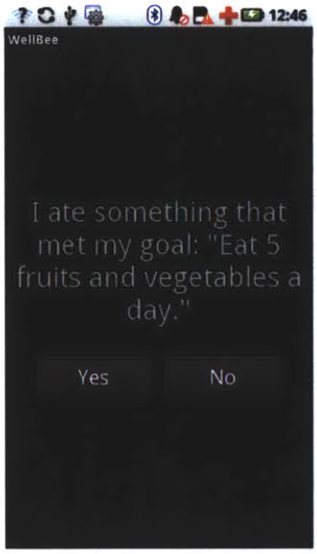


Figure 3-5: This diagram shows the question that appears when a user reports an eating incident.

4) Random EMA Assessments: In order to validate the decision algorithm and also collect additional subjective information, the standard EMA assessment mentioned above is also presented to the user at random time intervals, approximately 2-3 hours apart. At each occurrence, a message is first displayed "May I ask you a few questions?" If the user ignores this message, or responds "No," then the EMA will be reattempted after 15 minutes. Otherwise, the EMA with questions detailed in Section 3.1.2 below will proceed, followed by a therapeutic and empathetic message.

EMA Design

The assessment questions used in the WellBee system were created based on factors that had shown a correlation to binge eating in previous studies such as mood and affect. In order to limit cognitive load on the user, each set of assessment questions was limited to a maximum of 4 questions. Questions were chosen to help ascertain how strongly the participant was craving food ("I am tempted to eat."), the current activity of the patient ("Just now, I was"), the patient's present mood and affect ("I am feeling"). For the activity questions, the user is allowed to choose between activ-

Figure 3-6: This figure shows an example of the phone's response when the user reports an unhealthy eating incident.

ities such as Eating/preparing food, Commuting, Working, and Socializing/hanging out. For the stress, feeling, and eating temptation questions, the user moves a slider on a continuous scale that is subsequently discretized from 1 to 5. The actual scale has been hidden from the user to prevent input bias as recommended by Palmblad's user interface guidelines [17]. Figures 3-7 shows some sample screen shots used in these assessments.

Intervention Message Design

The therapeutic intervention used in our system is in the form of a motivational message paired with an image that is presented on the phone after the user finishes answering the assessment questions. The intervention message that is displayed depends on the user's responses to the assessment questions. The goal of the intervention messages are to provide empathy and support for the users, which we hope will in turn help them feel less stressed and more able to resist the temptation to eat unhealthy foods when they are stressed. We hope it will also support them to eat healthier in general by helping them meet the recommended dietary guidelines of

eating five fruits and vegetables a day. The empathetic intervention messages were developed based on some of the theories demonstrated in Klein's work [10] and Liu's work [11] which help minimize user frustration. Some techniques include acknowledging how the user feels and thanking them for taking the time to fill out the EMA. One example intervention message is "You've been great at giving me input. Really appreciate it, thanks & hope you can relax a bit more." Figure 3-8 shows an example of an intervention message displayed on the phone if the user reports being tempted to eat and in the assessment, reports that they are stressed. For a list of all the intervention messages used in the phone application, please refer to Appendix A.

Although not used for the study in this thesis, the system has some built-in support for customized intervention messages. These customized messages can be loaded into each patient's database via the centralized web server control panel which is discussed in Section 3.1.3. Upon uploading each intervention message, the server provides a means to rate the message according to its emotional impact or severity. This "intensity score" is then taken into account by the intervention engine that chooses the therapeutic content to be displayed.

3.1.3 System Administration

Web Server

A custom server JAVA application was created by another team member to support remote log-in and review of anonymous deidentified patient data and user settings. In addition to viewing patient sensor data and assessment results, a key feature was the means to remotely update and adjust the decision algorithm parameters on each patient's phone. Figure 3-9 is a screen shot of web server dashboard showing top-level web page for viewing patient data and editing patient settings. Data was stored on a remote Microsoft MS-SQL secure database server.

PC Application for Administration

I helped create a separate Java PC application for the purpose of enrolling participants and assigning phones and sensors bands to the participants so it is easy to track which phones and sensor bands as well as the data collected on these components belong to which participant. This program was designed for the study coordinator and enables a variety of data and updates to be downloaded to the phone as well as uploading data to the central server. The PC application is shown in Figure 3-10.

3.2 Design Challenges

WellBee was designed to continuously collect data from participants in situ and provide CBT to them as needed. Thus, the system must be usable, low power and ensure the privacy and security of participants' data. The following discusses how the system meets each of these requirements.

3.2.1 Usability

To increase usability of the system as well as participants' willingness to use the system, it needs to be unobtrusive. Thus, wireless, non-intrusive physiological sensors were developed for this system.

The mobile application is easy to learn and use. The user interfaces of the application have been designed such that they are clear and easy to use based on established for electronic diary interfaces [17]. There are two buttons on the Home Screen of the application, each of which launches a survey – one survey for the user to report when they are craving food or their feeling and the other for the user to report an incidence of eating. The surveys are short, consisting of only four questions, so they don't take up a lot of the participants' time.

3.2.2 Power

The battery drain of the phone and sensor band comes mainly from the continuous collection and transmission of the physiological measurements of the participants via Bluetooth. Yet, continuous sensor data collection is useful since it reveals information about the participant without having to bother the particpant. The limitation of the battery life of the system is the sensor band. However, the power consumption of WellBee sensors compares favorably with other similar sensor bands as reported in the literature [15, 3] and has a battery life of 9 to 10 hours.

3.2.3 Privacy and Security

When participants enroll in a study, they expect their data to be kept private, especially if they have to submit personal or private information. Potentially, they might even want their participation in the study to remain unknown to others. In the WellBee, the sensors used are worn around the ankle, which can be hidden under the participant's pant leg, if they want. Also, both the sensor band and phone record the physiological data collected so the data can still be recovered in case one of either the phone or the band goes missing.

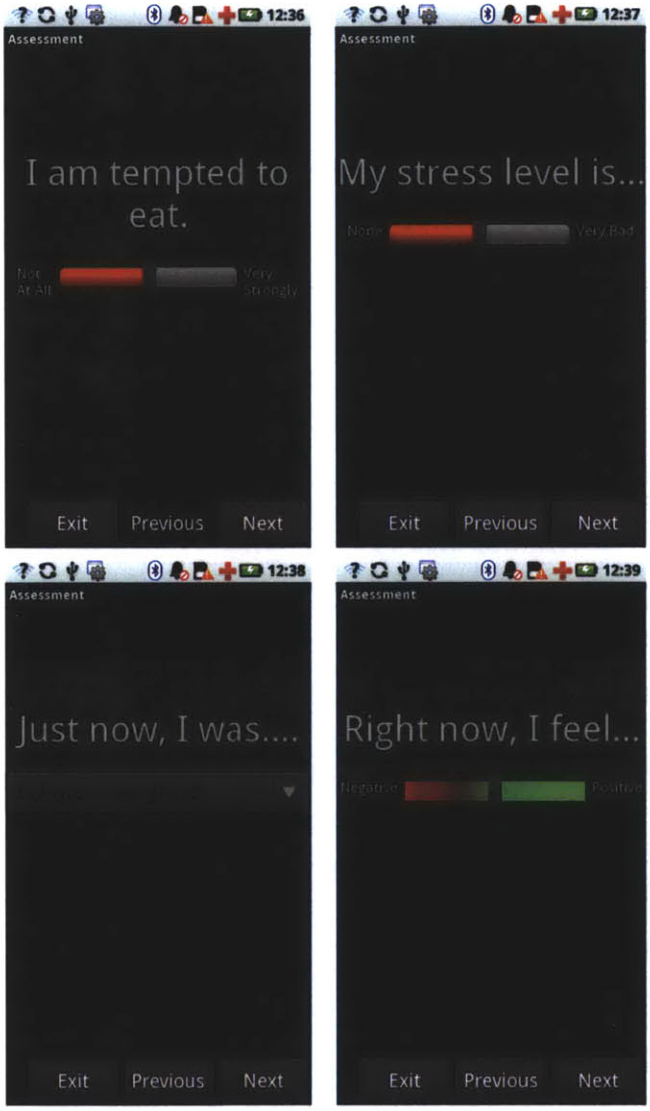


Figure 3-7: This figure shows the questions that make up the WellBee EMA

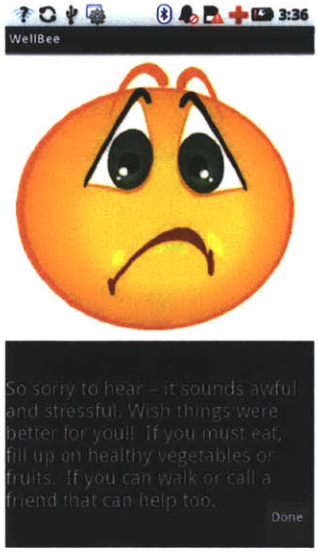


Figure 3-8: This diagram shows an intervention messages that appears after the user fills out the EMA.

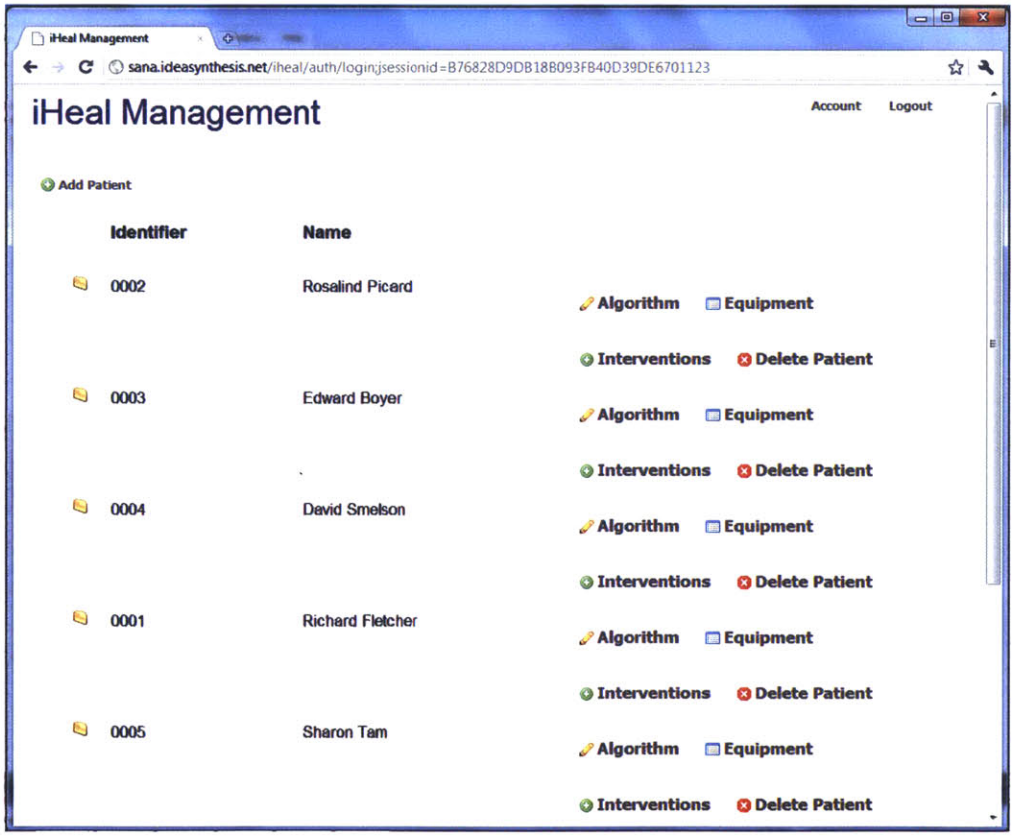


Figure 3-9: This shows the top level view of the Web Server for viewing patient data and editing patient settings.

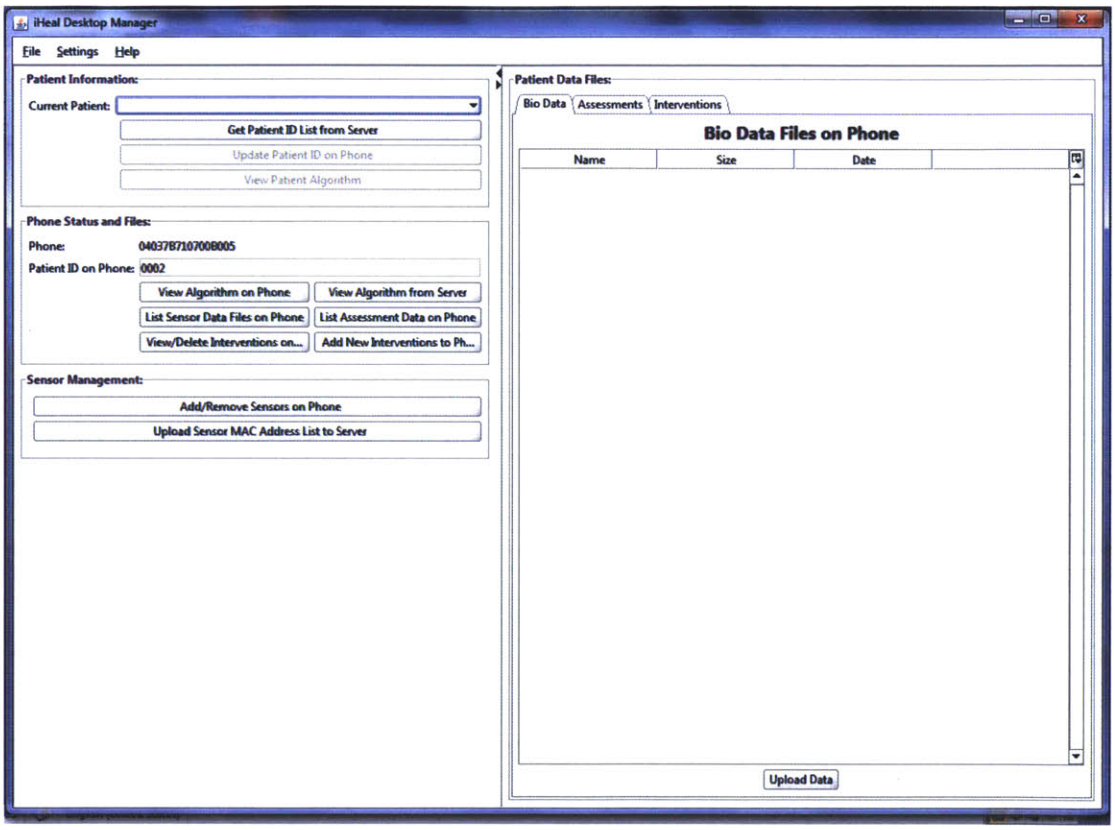


Figure 3-10: This shows the PC Application that acts as an interface for the transfer for data and updates between the phone and the server.

Chapter 4

Pilot study

4.1 Hypotheses

The hypotheses of this experiment include:

- H1: The WellBee version with empathetic messages will result in a decrease in participants' average reported stress.
- H2: WellBee will help participants decrease the number of times they eat non-target foods and increase the number of times they eat fruits and vegetables.
- H3: Wellbee will increase participants' daily awareness of level of stress and mood.
- H4: Participants will choose to continue working with the empathetic system.

4.2 Experimental Method

Day	Procedure
-	Participants recruited via email.
1	Participants come to laboratory for an introduction session. They sign a consent form, are taught how to use the system, are asked to use the system for three 4-day sessions, are given a sensor band and mobile phone, and are given a questionnaire for obtaining base-line stress levels, demographic information, and personality information.
1-5	Participants use the WellBee system. Some subjects have the empathetic version while others have the non-empathetic version although we just call them "system 1" and "system 2".
5	Participants come to laboratory for their second meeting to download their data, switch the version of their phone software, and fill out a questionnaire for obtaining their new stress levels and feeling levels.
5-9	Participants use the WellBee system. Some subjects have the empathetic version while others have the non-empathetic version. They will have the version of the system they didn't try in Days 1 to 4.
9	Participants come to the laboratory for their final meeting to download their data and are given a questionnaire to determine their stress level, mood level, and which version of the WellBee system they would like to use for the next four days. At the end of the session, they are told that the study is over and they do not have to continue using WellBee. They are asked an additional question of how happy they are that the study is over then they are debriefed and compensated.

4.3 Participant Recruiting

Participants were recruited via email solicitations to undergraduate dorms and living groups at MIT. I was looking for participants between ages 18 and 56, but ages of the eight participants were between 18 and 25, inclusive. Of the eight participants six were White Not-Hispanic, one was Asian, and one was Black/African American Not Hispanic. Six were students at MIT and the other two were technicians – one at MIT and the other not.

4.4 Experimental Protocol

During the first meeting, participants were told that the overall purpose of the study was to investigate people's stress patterns and how they correlate to their eating habits to develop an algorithm to recognize potential stress-eating patterns from the sensors. They were then asked to sign a consent form and were taught how to use the WellBee system. The participants were told that they would use one system for four days, a second system for the next four days, and a system of their choice for the last four days. Since the phone application included a setting for users to switch between system 1 and system 2, the participants were able to choose whether they wanted to start with "system 1" or "system 2" but they did not know what kind of system (with empathetic messages or without empathetic messages) they were using. The participants did not tell the experimenter which version they began with. It was important to keep the experimenter blind to the condition because she would see the participant before all the questionnaires for the study were completed. Finally, participants were given a questionnaire (see Appendix A) for obtaining base-line stress levels and demographic information.

For the first four days, participants used either the E (empathetic version) or the NE (without empathetic messages version). The participants were asked to wear

the sensor during their waking hours at least until the sensor ran out of battery. Participants were encouraged to continue reporting carving and eating incidences even after the sensor battery ran out. Participants were told to charge their sensors nightly and their phone as needed.

After the first four days, participants came into the laboratory to download their data. The participants were then told to switch their systems such that all participants that were in the E version were switched to the NE version and vice versa. Participants also filled out a questionnaire (see Appendix A).

Participants used the WellBee system for another four days. At the end of the second four days, the participants came into the laboratory for the final meeting to download their data and fill out the last questionnaire. After the questionnaire, they were told that the study was over and that they did not have to continue using the system. Participants were then told all the goals and design of the study, which condition they had been in, and compensated for their participation.

Chapter 5

Results

The following summarizes the results of the pilot study.

5.1 Results and Discussion

5.1.1 Average Stress Level

To determine if WellBee version E (with empathetic messages) will result in a decrease in participants' average reported stress compared to version NE (without empathetic messages), the average stress levels reported by the participants via random assessments, physiologically-triggered assessments, and self-reported assessments were taken. Figure 5-1 shows the average stress level for each system version by a participant.

The quantitative results collected from the study were analyzed using a one-tailed, two-sample, paired or unpaired t-test with a 90% confidence interval on each condition and system. One participant developed a rash due to being sensitive to the metals used in the sensor band and had to stop the study after the first four days. Thus, her data was not included in any of the following data analysis. From the t-test, there is not a significant difference in the average level of stress reported by participants

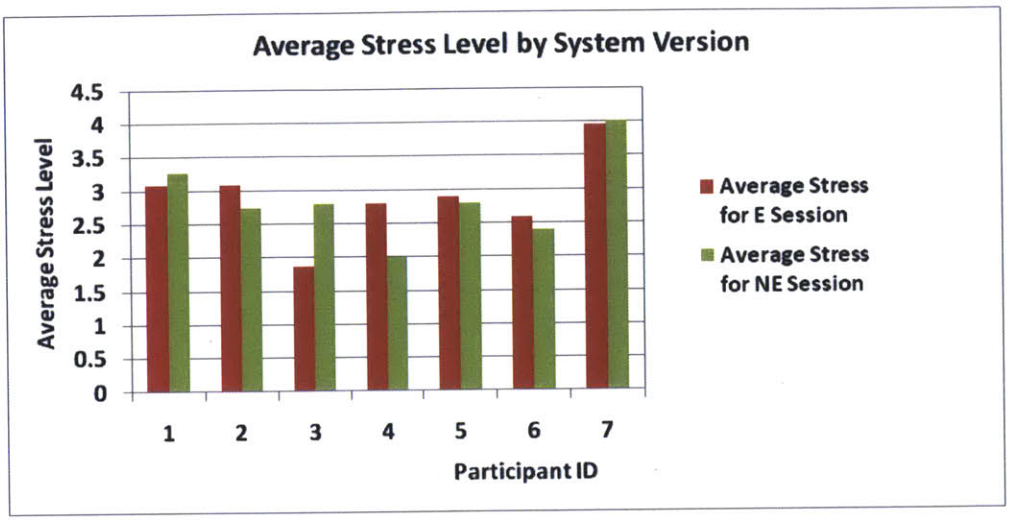


Figure 5-1: This figure shows the average stress level of assessments for each system version used by a participant.

when they used version E versus version NE, $t(6) = 1.44$ and $p = 0.44$. The mean stress level reported by the participants when they used version E was 2.89 (SD = 0.627). The mean stress level reported by the participants when they used version NE was 2.86 (SD = 0.638).

5.1.2 Eating Target Foods

To determine if WellBee version E will help participants decrease the number of times they eat non-target foods and increase the number of times they eat fruits and vegetables (target foods) compared to version NE, the percentage of reported eating incidences in which each participant ate a target food was calculated and are shown in Figure 5-2.

Based on a paired t-test performed on the data shown in Figure 5-2, no significant difference was found in the percentage of eating incidences that involved target foods between the first 4-day session and the second 4-day session with $t(6) = 1.44$ and $p = 0.443$. The mean percentage of eating incidences reported for the first session was 62.8% (SD = 0.251) and the mean percentage of eating incidences reported for the

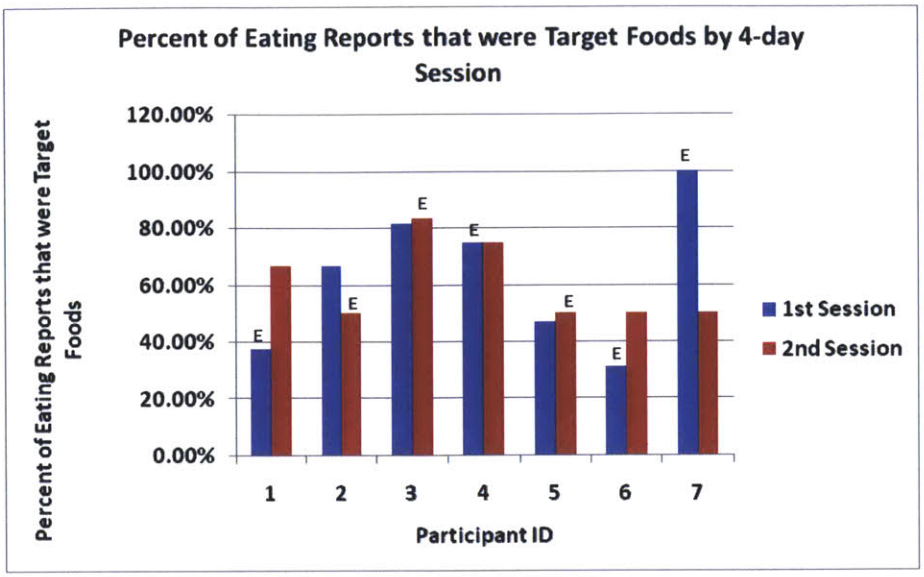


Figure 5-2: This figure shows the average percent of eating incidences that involved eating a target food broken down system version and condition.

second session was 60.7% (SD = 0.142).

Also, the percentage of reported eating incidences in which each participant ate a target food when using each system was calculated and are shown in Figure 5-3.

Based on the paired t-test performed on the data shown in Figure 5-3, no significant difference was found in the percentage of eating incidences that involved target foods between the times the participant was using the empathetic version compared to the non-empathetic version with $t(6) = 1.44$ and $p = 0.421$. The average percentage of eating incidences that involved target foods when a participant was using version E is 61.01% (SD = 0.255) and the average percentage of eating incidences that involved target foods when a participant was using verion NE is 62.46% (SD = 0.136).

As is common with self-report assessments, several participants admitted that they sometimes forgot to report when they craved or ate something. Also, some participants reported having a difficult time hearing the random assessment alerts and thus were unable to respond to them. Therefore, although my analysis based

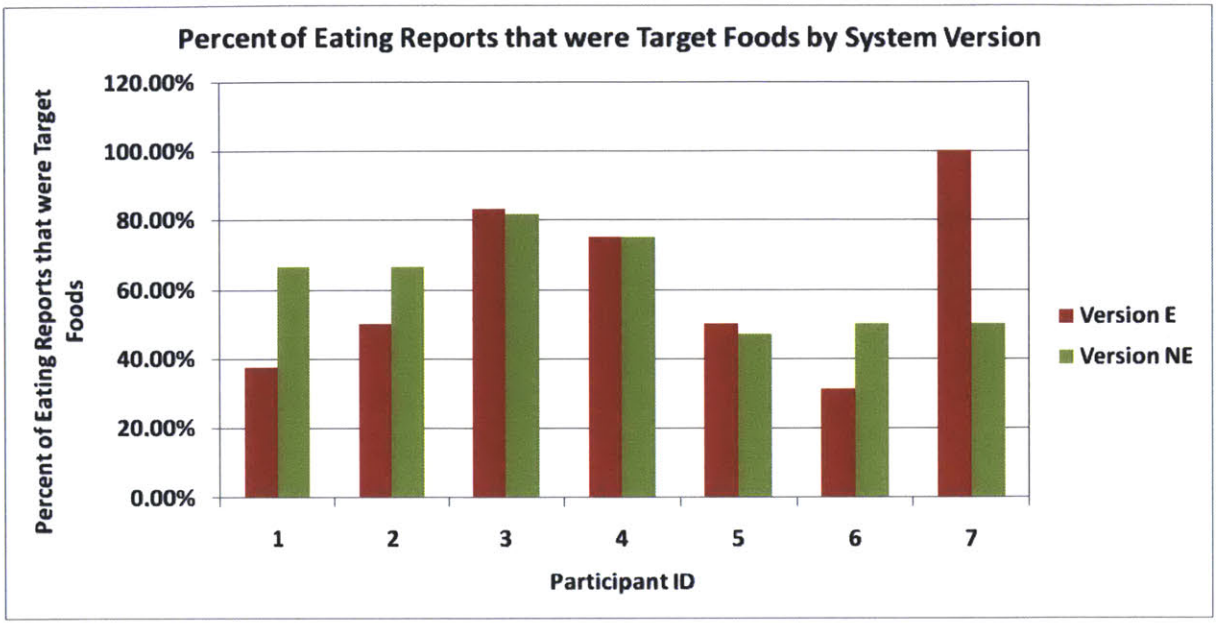


Figure 5-3: This figure shows the percent of eating incidences that involved eating a target food broken down by participant and system version.

on the data collected does not show any significant different between the E and NE versions, this may be due to lack of reported data. Table 5.1 shows how many eating and craving reports each participant initiated during each 4-day session.

Table 5.1: Number of Craving and Eating Reports by Participants

Participant ID	First Session Craving Reports	First Session Eating Reports	Second Session Craving Reports	Second Session Eating Reports
1	11	8	4	3
2	5	9	4	8
3	10	11	7	6
4	10	12	9	8
5	4	17	8	12
6	16	16	12	16
7	2	3	0	2

Table 5.2: Participant Estimated and Actual Stress and Mood Levels

Participant ID	4-day session	Estimated Average Stress Level (1=lowest))	Actual Average Stress Level	Estimated Average Mood Level (5=best)	Actual Mood Level
1	First	3	3.08	4	2.8
1	Second	2	3.27	4	2.81
2	First	3	2.73	3	3.00
2	Second	4	3.08	3	2.58
3	First	2	2.80	5	3.80
3	Second	2	1.86	4	4.58
4	First	3	2.80	2	3.80
4	Second	2	2.00	3	4.30
5	First	3	2.80	3	2.60
5	Second	4	2.88	3	2.63
6	First	2	2.58	4	3.58
6	Second	3	2.40	3	3.87
7	First	5	3.95	2	2.68
7	Second	5	4.00	2	3.50

5.1.3 Awareness of Stress Level and Mood

Most of the participants mentioned they felt that answering the assessment questions helped them be more aware of their eating habits, stress level, and mood. To determine if WellBee does help them be more aware of their stress level and mood, after each four-day session participants were asked to estimate their stress level and mood for the four-day session (Refer to Appendix A for the questionnaires). These estimates were compared with the actual average calculated from the levels input via the assessments that the participants filled out. Table 5.2 shows the estimated and actual average stress levels and mood for the participants for each four-day session.

The paired t-test comparing the estimated and actual stress levels resulted in $t(13) = 1.35$ and $p = 0.162$. The mean stress level estimated by the participants was 3.07

(SD = 1.07) and the mean stress actual stress levels reports by participants was 2.87 (SD = 0.608). As there is no significant difference between the estimated and actual stress levels, the action of answering the assessment questions may indeed make the user more aware of their stress level.

The paired t-test comparing the estimated and actual mood levels resulted in t(13) = 1.35 and p = 0.34. The mean mood level estimated by the participants was 3.21 (SD = 0.893) and the mean actual mood levels reports by participants was 3.32 (SD = 0.680). As there is no significant difference between the estimated and actual mood levels, the action of answering the assessment questions may also make the user more aware of their mood level.

When taking into account the condition they participants were in, the mean stress level estimated by the participants in condition NE to E was 3.00 (SD = 0.814) and the mean actual stress level was 2.69 (SD = 0.388). The mean mood level estimated by the participants in condition NE to E was 3.50 (SD = 0.764) and the mean actual stress level was 3.20 (SD = 0.750). The mean stress level estimated by the participants in condition E to NE was 3.13 (SD = 1.25) and the mean actual stress level was 3.01 (SD = 0.713). The mean mood level estimated by the participants in condition E to NE was 3.00 (SD = 0.926) and the mean actual stress level was 3.42 (SD = 0.592).

5.1.4 Overall System Evaluation

To determine which version of WellBee participants preferred, they were asked to what extent they would like to continue working with the system and how happy they were when they were told the study ended after the second four-day session.

The two-sample, unpaired t-test performed on the participants' answers to how happy they were that the study is over for each condition results in t(5) = 1.55 and p = 0.0981. The higher the score, the happier the participant is that it's over. The mean response for those in the E to NE condition was 5 (SD = 2.31) and the mean

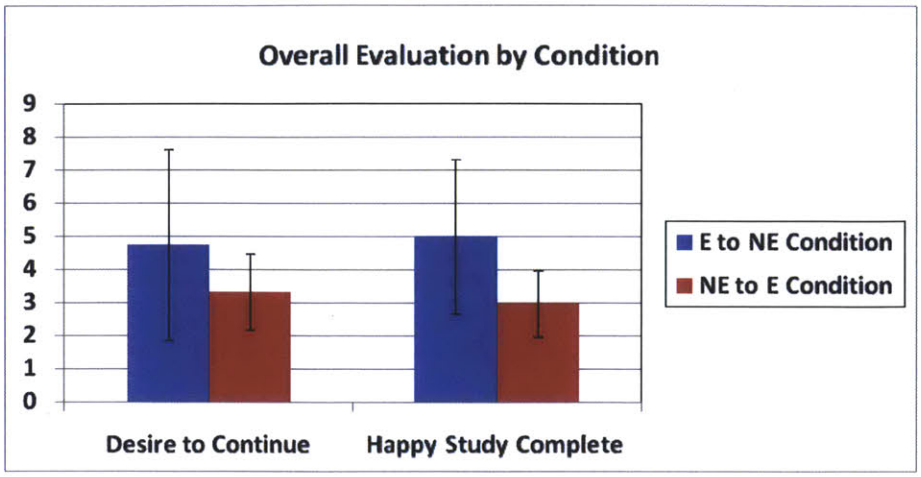


Figure 5-4: Overall System Evaluation

response for those in the NE to E condition was 3 (SD = 1.00). There is a significant difference in how happy participants were that the study is over where those in the E to NE condition were significantly happier it was over.

The two-sample, unpaired t-test on the participants' answers to what extent they would like to continue working with the system for each condition results in t = 0.895 and p = 0.211. The mean response for those in the E to NE condition was 4.75 (SD = 2.87) and the mean response for those in the NE to E condition was 3.33 (SD = 1.15). There is no significant difference to what extent participants want to continue working with the system.

Finally, the strongest indicator for which version of WellBee participants preferred is they were asked to choose the version they would like to use for the last four days. Table 5.3 summarizes the choices they made.

The reasons that participants 2 and 3 gave for choosing the version with empathetic messages were that the images made the message more colorful and the messages were inspirational. However, participants 1, 5, 6, and 7 said that the messages felt that the messages weren't helpful for them since they felt the messages

Table 5.3: Participant System Type for Each System

Participant ID	Session 1	Session 2	Session 3 Selection	Desire to Continue	Happy Study Complete
1	Empathetic	Non-empathetic	Non-empathetic	1	7
2	Non-empathetic	Empathetic	Empathetic	4	3
3	Non-empathetic	Empathetic	Empathetic	2	4
4	Non-empathetic	Empathetic	No preference	4	7
5	Empathetic	Non-empathetic	Non-empathetic	4	2
6	Empathetic	Non-empathetic	Non-empathetic	7	3
7	Empathetic	Non-empathetic	Non-empathetic	7	3

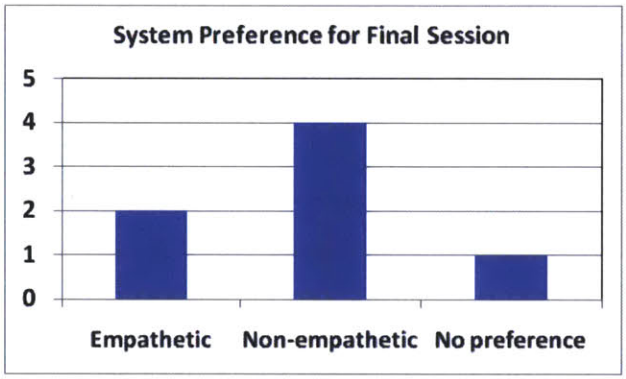


Figure 5-5: System Preference Results for All Subjects

seemed too empathetic to the point they seemed fake and sometimes condescending. Participant 6 said she does like having empathy from her friends, but receiving empathy from a phone is a different feeling. Participant 4 did not notice a difference in the two versions of the system.

6 out of 7 participants preferred the version of WellBee that they finished with. Yet, even though those participants who ended on version NE preferred version NE, they indicated they were happier that the study was finished which shows that the NE version isn't that desirable.

Each of the three questionnaires that the participants were asked to fill out included the EADES questionnaire which is a validated questionnaire that measures the constructs of emotion and stress related eating, appraisal of ability and resources

Table 5.4: Participant EADES scores

Participant ID	Questionnaire	EADES Factor 1	EADES Factor 2	EADES Factor 3
1	1	84	73	10
1	2	81	78	12
1	3	91	73	15
2	1	77	85	16
2	2	77	76	13
2	3	79	73	15
3	1	66	75	11
3	2	72	74	14
3	3	70	85	9
4	1	77	73	12
4	2	76	71	14
4	3	85	74	13
5	1	69	59	15
5	2	69	61	15
5	3	66	61	15
6	1	62	85	9
6	2	53	74	10
6	3	61	74	10
7	1	89	73	13
7	2	90	67	13
7	3	91	66	14

to cope, and appraisal of outside influences and stressors. Table 5.4 shows the scores each participant obtained for each questionnaire. Factor 1 measures one's emotion and stress related eating, factor 2 measures one's ability and resources to cope and factor 3 measures one's ability to deal with outside influences and stressors. The lower the score for each factor, the more compromised one's ability for that factor is.

Figure 5-6 shows the participants' average EADES Factor 1 score change while using each system version based on the condition (E to NE or NE to E) they were in. For participants in the condition where they used version E and then version NE, the average score change when they used version E was a decrease in 3 points (SD = 4.32) and the average score change when they used version NE was an increase in 4.5

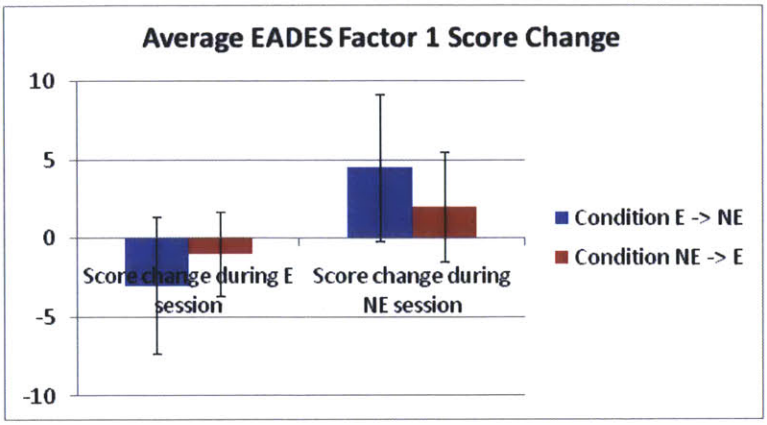


Figure 5-6: This figure shows the participants' average EADES Factor 1 score change while using each system version based on the condition (E to NE or NE to E) they were in.

points (SD = 4.65). For participants in the condition where they used version NE and then version E, the average score change when they used version E was a decrease in 1 points (SD = 2.65) and the average score change when they used version NE was an increase in 2 points (SD = 3.46).

Figure 5-7 shows the number of participants' whose EADES Factor 1 score increased, decreased, or stayed the same while using each system version based on the condition (E to NE or NE to E) they were in. After using version NE, 4 participants had a score increase and 3 participants had no change in their score. After using version E, 2 participants had a score increase and 5 participants had a score decrease.

Figure 5-8 shows the number of participants' whose EADES Factor 1 score increased, decreased, or stayed the same after using WellBee for the duration of the study.

WellBee shows potential in helping users cope with stress related eating since 5 of the 7 participants had an increase in their EADES Factor 1 score after using WellBee for the duration of the study. However, it's difficult to determine which version of the system is most beneficial to the users. 3 of the 4 participants that preferred version NE had a score increase when using version NE while only 1 of the 3 participants

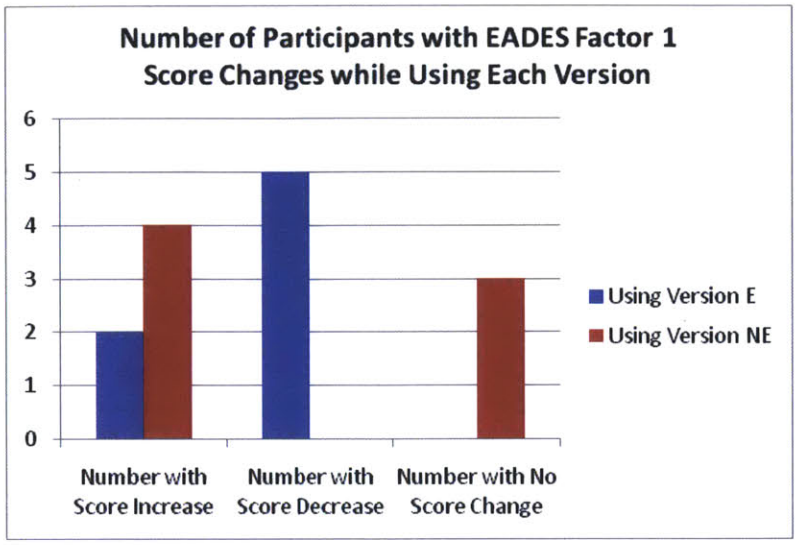


Figure 5-7: This figure shows the number of participants whose EADES Factor 1 score increased, decreased, or stayed the same while using each system version

that preferred version E had a score increase when using version E.

5.2 Participant Feedback

One thing that almost all participants noted were the vibration alerts for the random assessment, physiology-triggered events, or the notification that the sensor had been disconnected. Some participants said the alerts were much to loud and annoying while others said they had a hard time hearing it. This is probably due to the environment they are in at the time of the alert. Those participants who were usually sitting in a classroom or working at an office job for most of the day tended to think the alerts were too loud and annoying. While those who were out and about most of the time they were working with the phone seemed to think the alert wasn't loud enough. Another thing several participants complained about was that when they reported a craving or eating incident, the phone asks if they ate something toward their goal of eating five fruits and vegetables and even though they felt they had eaten something healthy that was not a fruit or vegetable, they were forced to answer "No" and they

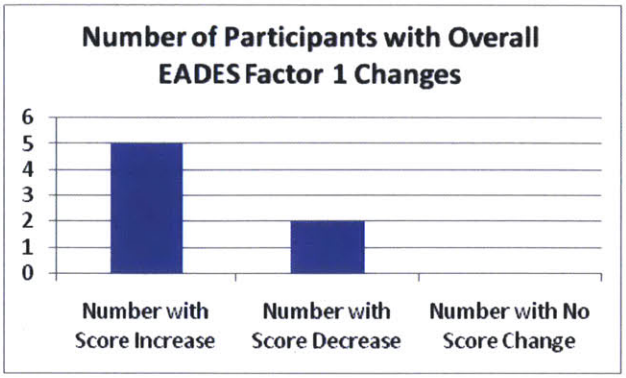


Figure 5-8: This figure shows the number of participants whose EADES Factor 1 score increased, decreased, or stayed the same after using WellBee for the duration of the study.

would feel guilty about it. Further, Participant 6 wished there were other things she could do to interact with the system, such as games or videos to watch. She said she wanted to use the phone more, but there were no opportunities to do so with WellBee since the only features of WellBee were pretty much report cravings or feelings and report eating incidences.

5.3 Summary

The results of this study were surprising and not what was hypothesized based on previous work such as Liu's and Klein's work [11, 10]. One possible explanation for why the majority of participants preferred version NE is that the participants come from the MIT community and the MIT community tend to emphasize thinking over feeling. The MIT community is definitely not representative of the general population. Although version E did not seem to help decrease participants' average reported stress nor help participants decrease the number of times they eat non-target foods and increase the number of times they eat fruits and vegetables and it was not the preferred version for the majority of participants, the empathetic version did seem more enjoyable to those who preferred that version and those that preferred version

E seemed more willing to continue with the study if that had been necessary. This is probably because the empathy helps the user develop a personal relationship with the phone and this relationship makes using the device more enjoyable. This does agree with the findings of Bickmore's PhD thesis which demonstrates that having a bond with a computer can affect a person's attitudes and behavior and generally help them like it more and keep using it more [1]. Perhaps, those that preferred the non-empathetic version of WellBee need some other means instead of the empathetic messages or messages not as strong emotional language used in this study to help them develop such a personal relationship with the phone. This could be different messages or other methods, such as the games suggested by Participant 6. Increased usage of the phone may help the user develop a more personal relationship with the device.

Chapter 6

Conclusion

Overall, this thesis has made two main contributions: 1) a new system for gathering data to study people's eating habits as correlated with their mood and stress level via an Android phone and 2) insight into features that would encourage people to use in situ health monitoring systems.

Chapter 3 outlines the components of the WellBee (and iHeal) system including some features that have been built into the system but were not used in this study such as the customizability of intervention messages. To the best of our knowledge, this is the first system that allows for continuous, wireless, non-intrusive data collection of EDA, accelerometer, and skin temperature in the user's natural environment while providing affective support when needed via an Android phone.

Chapter 5 highlighted our findings of how useful the WellBee system is to make the user aware of their stress and mood, what features of WellBee users liked and what features users would like to have incorporated into a system like WellBee. Although the result that the non-empathetic version was preferred by 4 of 7 of participants, the results seemed to confirm that helping a user develop a personal relationship with the mobile phone may be the key to getting users to use such health monitoring systems in the long term. However, empathetic message may be one way to help users develop

such a relationship, but it might not be the only way or even the best way to help all users.

Yet, there were some limitations to this study as well as some areas of future work that should be addressed to provide a more satisfactory experience for users of future versions of WellBee or similar systems.

6.1 Limitations of Study

A main limitation is the small sample size. Also, these eight participants might not be representative of the MIT female student population let alone the target audience of the phone application. Another limitation may be the duration of the study is too short, since the novelty of using a mobile phone may not have worn off after 8 days. If the duration of the study were increased, whether the empathy helps participants stick with using the phone may become more apparent. Also, as aforementioned, participants often forgot to report cravings or eating incidences until after the fact and they weren't able to report incidences that had occurred in the past, so some data was probably lost due to this.

6.2 Future Work

There are many ways the WellBee system can be improved further. In general, it has been shown from this study that the WellBee system needs to be more customizable and let the user have more control over the features of the application to be useful. For example, the system should let the user control the intensity of the vibration alerts, allow them to mute the application for specified length of time, and allow them to report craving and eating incidents up to some duration after the incident, and allow the users to specify their own goal instead of using the default goal of the study: "Eat 5 fruits and vegetables". Future studies can allow participants to create

their own intervention messages and see if that has a more positive effect on helping them cope with stress-related eating. The WellBee system can be further improved by the addition of more eating intervention techniques, especially for use by those with more severe eating problems. One such technique may be to include a Hunger Scale that allows the user to read the descriptions on the scale to determine how hungry he/she really is. Oftentimes, people can't really tell how hungry they are.

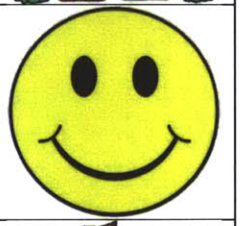
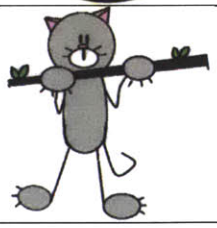
6.3 Conclusion

This thesis has made several important contributions to the field of using technology to help people cope with stress-related eating. The WellBee system developed for the pilot study shows potential for helping users cope with stress-related eating and along with the results of the pilot study, serves as a good starting point for those who would like to build similar mobile therapy systems in the future.

Appendix A

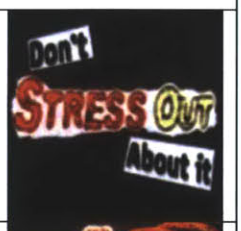
Appendix A

A.1 Eating Messages

Stress Level (1 None – 5 Very Bad)	Feeling positive/negative	Has any cravings for food (Yes/No)?	Messages	Image
1	Positive	Yes	You are stronger than you think and can overcome this temptation to eat. Ask yourself "Are you really hungry?"	
1	Positive	No	Great to hear you're doing well! So happy to hear things are going great!	
1	Negative	Yes	☹ You can overcome the temptation to eat. Hang in there!	

Stress Level (1 None – 5 Very Bad)	Feeling positive/negative	Has any cravings for food (Yes/No)?	Messages	Image
1	Negative	No	I'm sorry to hear you're not in a good mood. I hope things look up soon for you.	
2	Positive	Yes	Take a few minutes and chill. Forget about everything except your goal to eat healthy – and stick with it.	
2	Positive	No	Seems like things are going pretty well. Nice. Sounds like things are pretty good.	
2	Negative	Yes	☹ Remember: Recognizing your food cravings puts you in control. Now, just resist the temptation to eat unhealthy foods and eat a fruit of vegetable instead. You can conquer this hurdle!	
2	Negative	No	I'm sorry to hear you're not in a good mood, I hope things look up soon. Thanks for your input.	
3	Positive	Yes	If you're really stressed, try to take a break, get outside or go do something you like. The most important thing right now is staying strong and resisting junk food.	
3	Positive	No	You've been great at giving me input. Really appreciate it, thanks & hope you can relax a bit more. Hope you can relax. Please keep me informed. Hope the stress can go a bit lower still – keep up the great input. Thanks & hope the stress lowers even more. Until next time.	

Stress Level (1 None – 5 Very Bad)	Feeling positive/negative	Has any cravings for food (Yes/No)?	Messages	Image
3	Negative	Yes	Sorry it's not good. You can feel better without turning to food for comfort. Try relaxing, breathe and focus on your goals. Doesn't sound good. But you can do anything you set your mind to. Just take it one step at a time.	 
3	Negative	No	Sounds like things are kind of bad. Thanks so much for all your input. Stay positive. Hope things get better soon. Here's a hug to help you feel better :). Sorry to hear it's not great. I hope answering these questions wasn't too frustrating. Here's a hug to help you feel better :).	
4	Positive	Yes	Sorry it's stressful. Do something healthy to manage what's stressing you out. Seek someone to talk to if you need it. The stress sounds awful. If you need to nibble to de-stress, remember you can eat a lot of fruits or vegetables.	
4	Positive	No	Sounds like you're pretty stressed but doing ok. Hope it chills soon.	

Stress Level (1 None – 5 Very Bad)	Feeling positive/negative	Has any cravings for food (Yes/No)?	Messages	Image
4	Negative	Yes	Sounds like things are really bad and stressful. Sorry!! Now is the time to be especially careful about what you eat. Choose smart and it will help you through this. Sorry to hear it's so bad now -- hope things calm down and get better. Please don't eat badly and make it worse. Hope it gets better soon.	
4	Negative	No	Sounds like things are really bad and stressful. I'm sorry that you're feeling stressed. Sorry to hear it's so bad now -- hope things calm down and get better.	
5	Positive	Yes	The stress sounds awful – it could really make you want to eat! This sounds like a tough time to hang in there and do the right thing, but now is the time to resolve to eat wisely. What else can you do to reduce your stress?	
5	Positive	No	Glad your mood is up but sorry to hear that you're stressed; hope things calm soon. Things sound good but really intense. Hope you can relax a bit.	

Stress Level (1 None – 5 Very Bad)	**Feeling positive/negative**	**Has any cravings for food (Yes/No)?**	**Messages**	**Image**
5	Negative	Yes	Wow. You sound stressed and maybe upset. ☹ Hope things start going better. Food may help you feel better, but choose the right foods. Try eating as much vegetables and fruits as you can and filling up on these. Can you also call a friend or go for a walk? So sorry to hear – it sounds awful and stressful. Wish things were better for you!! If you must eat, fill up on healthy vegetables or fruits. If you can walk or call a friend that can help too.	
5	Negative	No	I know it's tough, but each day contains its own challenges. Don't give up -- the good stuff is just around the corner. With perseverance and determination, you'll get there.	

A.2 Consent Form

CONSENT TO PARTICIPATE IN BIOMEDICAL RESEARCH

Stress Awareness Survey from Mobile Sensors

You are asked to participate in a research study conducted by Sharon Tam from the Affective Computing Group at the Massachusetts Institute of Technology (M.I.T.) Media Laboratory. You have been asked to participate in this study because you are interested in understanding more about the different stress patterns in your own life. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

- **PARTICIPATION AND WITHDRAWAL**

Your participation in this research is completely VOLUNTARY. If you choose to participate you may subsequently withdraw from the study at any time without penalty or consequences of any kind. If you choose not to participate, that will not affect your relationship with M.I.T. or your right to health care or other services to which you are otherwise entitled.

- **PURPOSE OF THE STUDY**

The purpose of the study is to collect perceived stress and activity information in order to investigate the nature and patterns of stress in people's daily lives and the effects stress has on their eating habits. The data collected will be used to develop new algorithms for detecting activity from sensors and identifying stress from physiological signals.

- **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things:

- Attend three 45min. lab sessions where you will be asked to complete a questionnaire about your thoughts, habits, and daily stress levels.
- At the end of the first lab session, the experience-sampling portion of the study will be explained to you. You will be given a mobile phone along with a wireless sensor band. The phone will alert you randomly throughout the day, 3-4 times a day. You will use this phone to record your perceived stress, mood, and activities for a 2-week period. Each entry should take less than 2 minutes to complete and can also be initiated by you if there is a significant event that occurs.

- You will be asked to visit the lab three times (two additional times), every week of the study to (1) upload your data and (2) complete additional laboratory tasks.
- A copy of your MIT identification or driver's license will be taken to ensure the security of the mobile phone and sensor band in your possession during the 2-week sampling period. If you miss a scheduled lab session and are out of touch with the experimenter for more than 48 hours after that time, we will have to report to the MIT police that the phone and sensor band are missing.

- **POTENTIAL RISKS AND DISCOMFORTS**

The device will need to disrupt you frequently throughout the day in order to gather data. If any discomfort is felt due to the device beeping and interrupting, you can mute the device temporarily or, if the device is causing serious discomfort, put the mobile phone down, take the sensors off and stop carrying them.

Should you experience ill effects or have questions/concerns regarding the study, please contact the investigators (information listed at the end of this consent form). If you experience any ill effects (either mentally or physically) during or after the study, inform the investigators immediately.

The treatment or procedure may involve risks that are currently unforeseeable.

- **ANTICIPATED BENEFITS TO SUBJECTS**

Based on experience with similar devices used in other healthy students, researchers believe it may be of benefit to subjects similar to you. Of course, because individuals respond differently to therapy, no one can know in advance if it will be helpful in your particular case. The potential benefits may include:

- *Self-knowledge*: People often gain valuable and interesting insights into their own experiences through research participation. This study will allow you to become more aware of the stressful areas of your life and how that stress might be causing stress-related eating.

- **ANTICIPATED BENEFITS TO SOCIETY**

When you participate in research, you have the benefit of knowing that the science you read about is based on real people like you. Like other volunteer activities, you are contributing to the greater community when you volunteer for research. The results of this work may help engineers improve the design of mobile computing devices used for behavioral therapy, as well as help numerous researchers design data collection tools to study not only stress, but various human phenomenon.

- **PAYMENT FOR PARTICIPATION**

In exchange for your participation, you will receive $70 ($5 for each day of participation), plus a bonus of $25 for completion the study and returning the phone and sensor band. If at any time, you have to withdraw from the study due to discomfort or illness, you will be paid for the days that you did participate in the study.

- **FINANCIAL OBLIGATION**

Neither you nor your insurance company will be billed for your participation in this research.

- **PRIVACY AND CONFIDENTIALITY**

The only people who will know that you are a research subject are members of the research team and, if appropriate, your physicians and nurses. No information about you, or provided by you during the research will be disclosed to others without your written permission, except: if necessary to protect your rights or welfare, or if required by law.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity. If photographs, videos, or audio-tape recordings of you will be used for educational purposes, your identity will be protected or disguised.

A.3 Session One Questionnaire

Session One Questionnaire

The EADES (Eating and Appraisal Due to Emotions and Stress) Questionnaire

The following questionnaire was developed to assess how individuals cope with and appraise stress in relation to food and eating. Your participation will assist in research related to why people overeat. This assessment will take about 10-15 minutes to complete. Your answers are confidential. There are a total of 58 questions.

Instructions: Please determine your level of agreement with the following statements. There are no right or wrong answers. Treat each question separately and answer as honestly as possible. It is important that you answer all questions. Choose only one answer per statement. Please respond to items 1-49 as follows:

1. If you **strongly disagree** with the statement
2. If you **disagree** with the statement.
3. If you are **neutral** to the statement.
4. If you **agree** with the statement.
5. If you **strongly agree** with the statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	My family supports me when I have problems.	1	2	3	4	5
2.	I am confident I can control my eating when I feel happy.	1	2	3	4	5
3.	I overeat when I am stressed.	1	2	3	4	5
4.	I can usually work out a solution to my problems.	1	2	3	4	5
5.	I am capable of handling my own problems.	1	2	3	4	5
6.	I do NOT feel secure in my life.	1	2	3	4	5
7.	I try to find alternative solutions to my problems.	1	2	3	4	5
8.	I overeat when I socialize.	1	2	3	4	5
9.	I weigh the pros and cons of situations before I make decisions about what to do.	1	2	3	4	5
10.	I worry about what people think of me.	1	2	3	4	5
11.	I comfort myself with food.	1	2	3	4	5
12.	I eat when I am upset with myself.	1	2	3	4	5
13.	I feel the need to make others happy.	1	2	3	4	5
14.	I am confident I can control my eating when I am tired.	1	2	3	4	5
15.	My friends support me when I have problems.	1	2	3	4	5
16.	I feel sad often.	1	2	3	4	5
17.	I am confident I can control my eating when I am angry.	1	2	3	4	5
18.	I am able to meet my emotional needs.	1	2	3	4	5
19.	It is hard for me to stop eating when I am full.	1	2	3	4	5
20.	I am able to say no when I need to.	1	2	3	4	5
21.	I try to think positive when times are tough.	1	2	3	4	5
22.	I am confident I can control my eating when I am sad.	1	2	3	4	5

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
23.	I have control over my emotions.	1	2	3	4	5
24.	I eat to avoid dealing with problems.	1	2	3	4	5
25.	I talk about my feelings.	1	2	3	4	5
26.	I am confident I can control my eating when I am upset with myself.	1	2	3	4	5
27.	Other people influence how I handle problems.	1	2	3	4	5
28.	I deal with problems sooner rather than later	1	2	3	4	5
29.	I try to resolve a problem when I know there is something wrong in my life.	1	2	3	4	5
30.	I am confident I can control my eating when I feel upset.	1	2	3	4	5
31.	I feel out of control when I eat.	1	2	3	4	5
32.	I eat when I am frustrated.	1	2	3	4	5
33.	I am capable of dealing with stressful situations.	1	2	3	4	5
34.	I am confident I can control my eating when I am frustrated.	1	2	3	4	5
35.	I use food to cope with my emotions.	1	2	3	4	5
36.	I am able to meet my spiritual needs.	1	2	3	4	5
37.	I eat when I am tired.	1	2	3	4	5
38.	I do NOT allow people to change my mind.	1	2	3	4	5
39.	I eat when I am angry.	1	2	3	4	5
40.	I eat when I am sad.	1	2	3	4	5
41.	When a problem arises, it is hard for me to make a plan of action and follow it.	1	2	3	4	5
42.	I am confident I can control my eating when I am anxious.	1	2	3	4	5
43.	I do NOT see challenges as stressful.	1	2	3	4	5
44.	I am confident I can control my eating when I am relieved.	1	2	3	4	5
45.	I eat when I am anxious.	1	2	3	4	5
46.	I have control over my life.	1	2	3	4	5
47.	I eat when I am relieved.	1	2	3	4	5
48.	I try to analyze a problem in order to better understand it.	1	2	3	4	5
49.	I do NOT have control over how much I eat.	1	2	3	4	5

Tell us a little about yourself by answering questions 50-55. Circle the statement that **best** represents you.

50. On a scale of 1 to 5, how would you describe your awareness of your daily stress levels (1 – Very Aware, 5 – Not Very Aware)?

    1 2 3 4 5

On a scale of 1 to 5, how would you describe your average level of stress over the past four days (1 – None, 5 – Very Bad)?

1 2 3 4 5

On a scale of 1 to 5, how would you describe your average mood over the past four days (1 – Very Negative, 5 – Very Positive)?
?

1 2 3 4 5

51. Which of the following represents your job category?
A.Student
B.Staff
C.Other _____

52.How do you describe yourself?
A. American Indian of Alaska Native
B. Asian
C. Black or African American-Not Hispanic
D. Hispanic or Latino
E. Native Hawaiian or Other Pacific Islander
F. White-Not Hispanic

For Questions 53-55, write your answers on the lines provided.

53. How old are you (Example: 45)?
Age in Years: ___ ___

54. How much do you weigh without your shoes on (Example: 185)?
Weight in pounds: ___ ___ ___

55. How tall are you without your shoes on (Example: 5 Feet 07 Inches)?
___ Feet ___ ___ Inches

Created by Amy D. Ozier PhD, RD, LDN, CHES
The order or wording of Questions 50-55 have been altered from the original by Sharon Tam, the author of this thesis.
For use: Contact aozier@niu.edu

A.4 Session Two Questionnaire

The following questionnaire is the same as the one used for Session One. However, we changed a few questions are the very end.

Session Two Questionnaire

The EADES (Eating and Appraisal Due to Emotions and Stress) Questionnaire

The following questionnaire was developed to assess how individuals cope with and appraise stress in relation to food and eating. Your participation will assist in research related to why people overeat. This assessment will take about 10-15 minutes to complete. Your answers are confidential. There are a total of 49 question in the EADES questionnaire.

Instructions: Please determine your level of agreement with the following statements. There are no right or wrong answers. Treat each question separately and answer as honestly as possible. It is important that you answer all questions. Choose only one answer per statement. Please respond to items 1-49 as follows:

1. If you **strongly disagree** with the statement
2. If you **disagree** with the statement.
3. If you are **neutral** to the statement.
4. If you **agree** with the statement.
5. If you **strongly agree** with the statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	My family supports me when I have problems.	1	2	3	4	5
2.	I am confident I can control my eating when I feel happy.	1	2	3	4	5
3.	I overeat when I am stressed.	1	2	3	4	5
4.	I can usually work out a solution to my problems.	1	2	3	4	5
5.	I am capable of handling my own problems.	1	2	3	4	5
6.	I do NOT feel secure in my life.	1	2	3	4	5
7.	I try to find alternative solutions to my problems.	1	2	3	4	5
8.	I overeat when I socialize.	1	2	3	4	5
9.	I weigh the pros and cons of situations before I make decisions about what to do.	1	2	3	4	5
10.	I worry about what people think of me.	1	2	3	4	5
11.	I comfort myself with food.	1	2	3	4	5
12.	I eat when I am upset with myself.	1	2	3	4	5
13.	I feel the need to make others happy.	1	2	3	4	5
14.	I am confident I can control my eating when I am tired.	1	2	3	4	5
15.	My friends support me when I have problems.	1	2	3	4	5
16.	I feel sad often.	1	2	3	4	5
17.	I am confident I can control my eating when I am angry.	1	2	3	4	5
18.	I am able to meet my emotional needs.	1	2	3	4	5
19.	It is hard for me to stop eating when I am full.	1	2	3	4	5
20.	I am able to say no when I need to.	1	2	3	4	5
21.	I try to think positive when times are tough.	1	2	3	4	5
22.	I am confident I can control my eating when I am sad.	1	2	3	4	5

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
23.	I have control over my emotions.	1	2	3	4	5
24.	I eat to avoid dealing with problems.	1	2	3	4	5
25.	I talk about my feelings.	1	2	3	4	5
26.	I am confident I can control my eating when I am upset with myself.	1	2	3	4	5
27.	Other people influence how I handle problems.	1	2	3	4	5
28.	I deal with problems sooner rather than later	1	2	3	4	5
29.	I try to resolve a problem when I know there is something wrong in my life.	1	2	3	4	5
30.	I am confident I can control my eating when I feel upset.	1	2	3	4	5
31.	I feel out of control when I eat.	1	2	3	4	5
32.	I eat when I am frustrated.	1	2	3	4	5
33.	I am capable of dealing with stressful situations.	1	2	3	4	5
34.	I am confident I can control my eating when I am frustrated.	1	2	3	4	5
35.	I use food to cope with my emotions.	1	2	3	4	5
36.	I am able to meet my spiritual needs.	1	2	3	4	5
37.	I eat when I am tired.	1	2	3	4	5
38.	I do NOT allow people to change my mind.	1	2	3	4	5
39.	I eat when I am angry.	1	2	3	4	5
40.	I eat when I am sad.	1	2	3	4	5
41.	When a problem arises, it is hard for me to make a plan of action and follow it.	1	2	3	4	5
42.	I am confident I can control my eating when I am anxious.	1	2	3	4	5
43.	I do NOT see challenges as stressful.	1	2	3	4	5
44.	I am confident I can control my eating when I am relieved.	1	2	3	4	5
45.	I eat when I am anxious.	1	2	3	4	5
46.	I have control over my life.	1	2	3	4	5
47.	I eat when I am relieved.	1	2	3	4	5
48.	I try to analyze a problem in order to better understand it.	1	2	3	4	5
49.	I do NOT have control over how much I eat.	1	2	3	4	5

Created by Amy D. Ozier PhD, RD, LDN, CHES
The order or wording of Question 50 has been altered from the original by Sharon Tam, the author of this thesis.

For use: Contact aozier@niu.edu

Please answer the additional questions below:

50. On a scale of 1 to 5, how would you describe your awareness of your daily stress levels (1 – Very Aware, 5 – Not Very Aware)?

1 2 3 4 5

On a scale of 1 to 5, what do you think was your average level of stress over the past four days (1 – None, 5 – Very Bad)?

1 2 3 4 5

On a scale of 1 to 5, what do you think your average mood over the past four days (1 – Very Negative, 5 – Very Positive)?
?

1 2 3 4 5

Are there suggestions or changes that you would make to the version of system you have been using for the past four days?

On a scale of 1 to 7, to what extent would you like to continue working with this version of the system (1 – Not at all, 7 – Yes, very much so)?

1 2 3 4 5 6 7

A.5 Session Three Questionnaire

The following questionnaire is the same as the one used for Session One. However, we changed a few questions are the very end.

Session Three Questionnaire

The EADES (Eating and Appraisal Due to Emotions and Stress) Questionnaire

The following questionnaire was developed to assess how individuals cope with and appraise stress in relation to food and eating. Your participation will assist in research related to why people overeat. This assessment will take about 10-15 minutes to complete. Your answers are confidential. There are a total of 49 question in the EADES questionnaire.

Instructions: Please determine your level of agreement with the following statements. There are no right or wrong answers. Treat each question separately and answer as honestly as possible. It is important that you answer all questions. Choose only one answer per statement. Please respond to items 1-49 as follows:

1. If you **strongly disagree** with the statement
2. If you **disagree** with the statement.
3. If you are **neutral** to the statement.
4. If you **agree** with the statement.
5. If you **strongly agree** with the statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	My family supports me when I have problems.	1	2	3	4	5
2.	I am confident I can control my eating when I feel happy.	1	2	3	4	5
3.	I overeat when I am stressed.	1	2	3	4	5
4.	I can usually work out a solution to my problems.	1	2	3	4	5
5.	I am capable of handling my own problems.	1	2	3	4	5
6.	I do NOT feel secure in my life.	1	2	3	4	5
7.	I try to find alternative solutions to my problems.	1	2	3	4	5
8.	I overeat when I socialize.	1	2	3	4	5
9.	I weigh the pros and cons of situations before I make decisions about what to do.	1	2	3	4	5
10.	I worry about what people think of me.	1	2	3	4	5
11.	I comfort myself with food.	1	2	3	4	5
12.	I eat when I am upset with myself.	1	2	3	4	5
13.	I feel the need to make others happy.	1	2	3	4	5
14.	I am confident I can control my eating when I am tired.	1	2	3	4	5
15.	My friends support me when I have problems.	1	2	3	4	5
16.	I feel sad often.	1	2	3	4	5
17.	I am confident I can control my eating when I am angry.	1	2	3	4	5
18.	I am able to meet my emotional needs.	1	2	3	4	5
19.	It is hard for me to stop eating when I am full.	1	2	3	4	5
20.	I am able to say no when I need to.	1	2	3	4	5
21.	I try to think positive when times are tough.	1	2	3	4	5
22.	I am confident I can control my eating when I am sad.	1	2	3	4	5

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
23.	I have control over my emotions.	1	2	3	4	5
24.	I eat to avoid dealing with problems.	1	2	3	4	5
25.	I talk about my feelings.	1	2	3	4	5
26.	I am confident I can control my eating when I am upset with myself.	1	2	3	4	5
27.	Other people influence how I handle problems.	1	2	3	4	5
28.	I deal with problems sooner rather than later	1	2	3	4	5
29.	I try to resolve a problem when I know there is something wrong in my life.	1	2	3	4	5
30.	I am confident I can control my eating when I feel upset.	1	2	3	4	5
31.	I feel out of control when I eat.	1	2	3	4	5
32.	I eat when I am frustrated.	1	2	3	4	5
33.	I am capable of dealing with stressful situations.	1	2	3	4	5
34.	I am confident I can control my eating when I am frustrated.	1	2	3	4	5
35.	I use food to cope with my emotions.	1	2	3	4	5
36.	I am able to meet my spiritual needs.	1	2	3	4	5
37.	I eat when I am tired.	1	2	3	4	5
38.	I do NOT allow people to change my mind.	1	2	3	4	5
39.	I eat when I am angry.	1	2	3	4	5
40.	I eat when I am sad.	1	2	3	4	5
41.	When a problem arises, it is hard for me to make a plan of action and follow it.	1	2	3	4	5
42.	I am confident I can control my eating when I am anxious.	1	2	3	4	5
43.	I do NOT see challenges as stressful.	1	2	3	4	5
44.	I am confident I can control my eating when I am relieved.	1	2	3	4	5
45.	I eat when I am anxious.	1	2	3	4	5
46.	I have control over my life.	1	2	3	4	5
47.	I eat when I am relieved.	1	2	3	4	5
48.	I try to analyze a problem in order to better understand it.	1	2	3	4	5
49.	I do NOT have control over how much I eat.	1	2	3	4	5

Created by Amy D. Ozier PhD, RD, LDN, CHES
The order or wording of Questions 50 has been altered from the original by Sharon Tam, the author of this thesis.
For use: Contact aozier@niu.edu

Please answer the additional questions below:

50. On a scale of 1 to 5, how would you describe your awareness of your daily stress levels (1 – Very Aware, 5 – Not Very Aware)?

1 2 3 4 5

On a scale of 1 to 5, what do you think was your average level of stress over the past four days (1 – None, 5 – Very Bad)?

1 2 3 4 5

On a scale of 1 to 5, what do you think your average mood over the past four days (1 – Very Negative, 5 – Very Positive)?
?

1 2 3 4 5

Are there suggestions or changes that you would make to the version of system you have been using for the past four days?

On a scale of 1 to 7, to what extent would you like to continue working with this version of the system (1 – Not at all, 7 – Yes, very much so)?

1 2 3 4 5 6 7

Which version of the system would you choose to use for the next four days?

Why did you choose the system that you did?

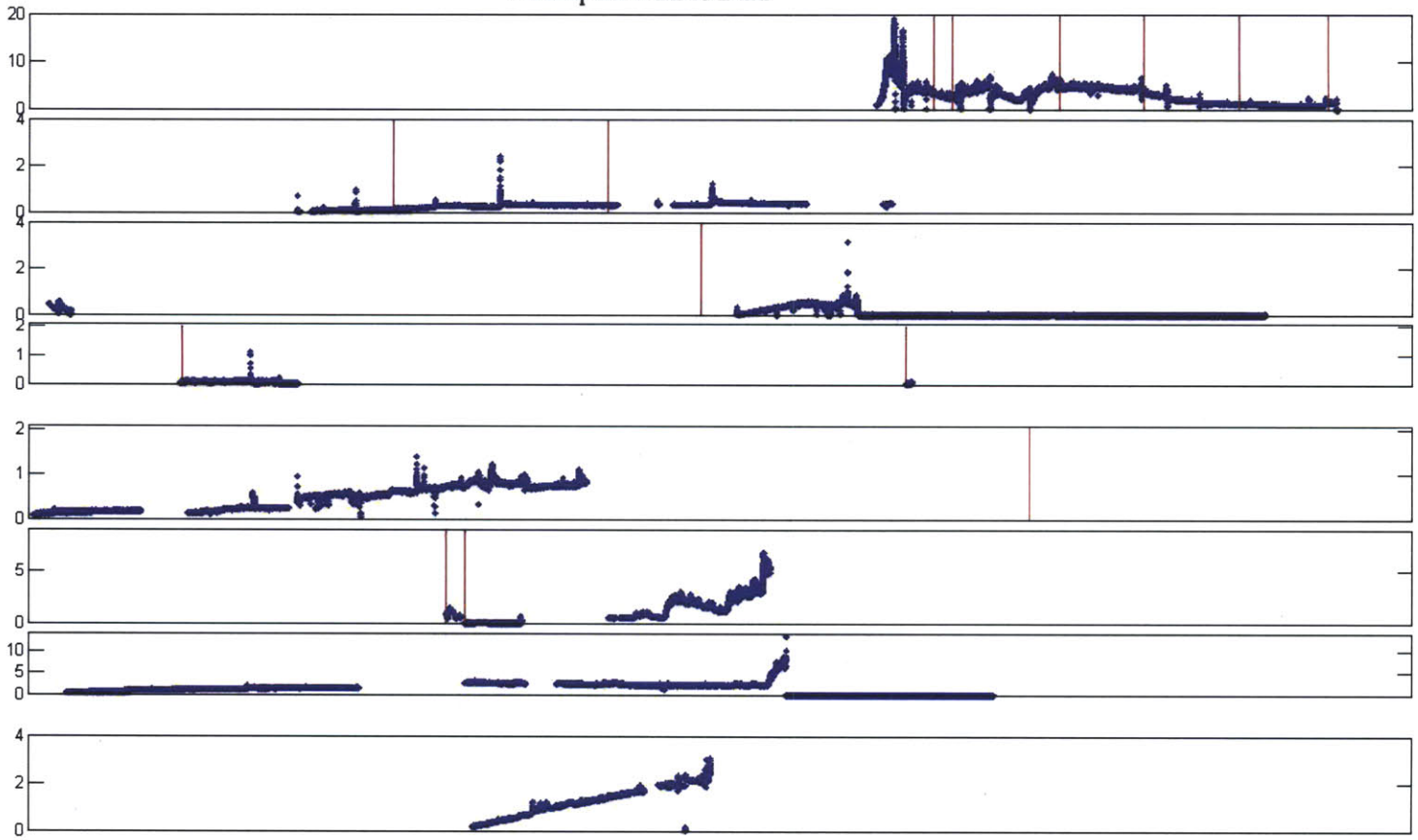
Any other comments or feedback on the system, sensors, experience, in general?

Appendix B

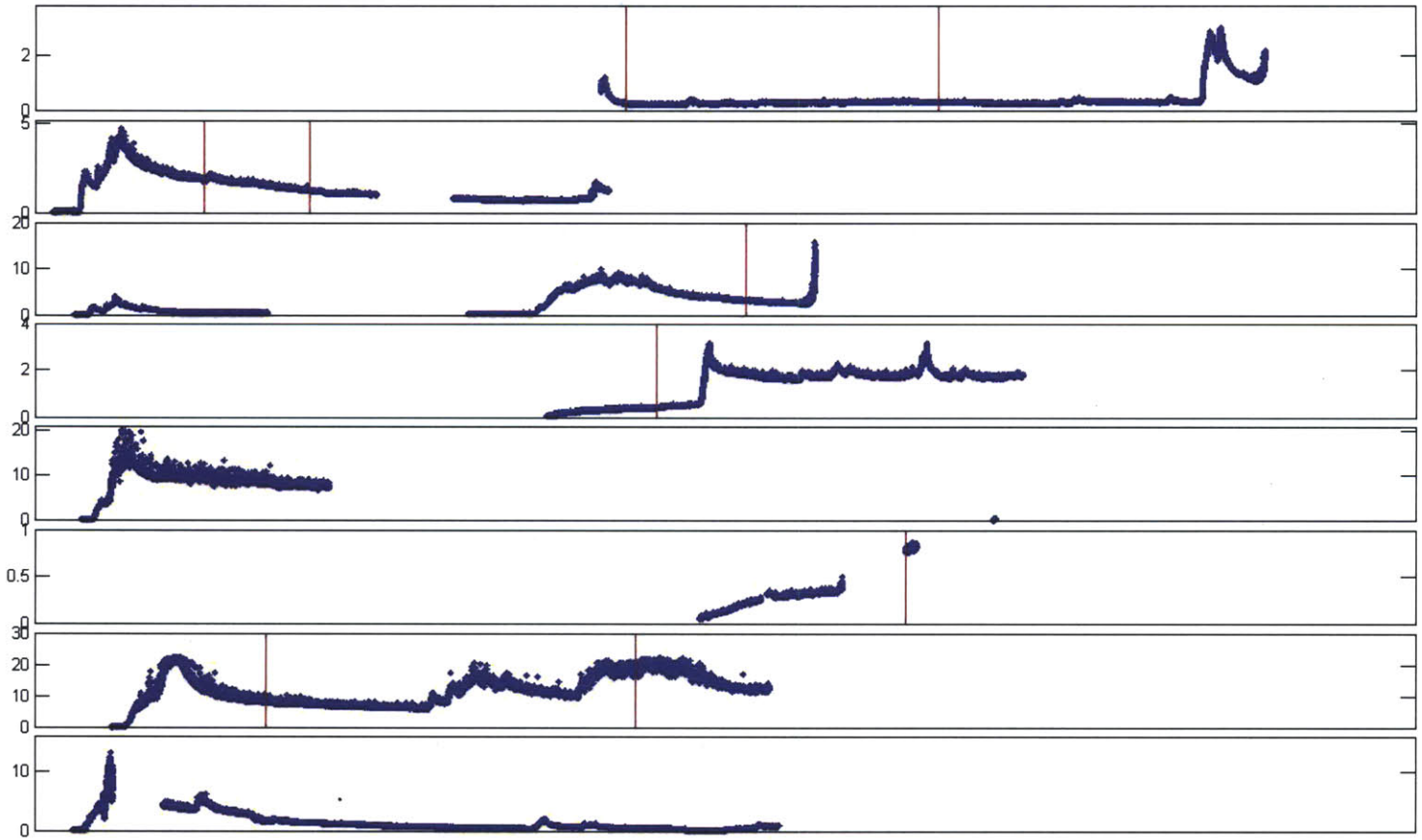
Appendix B

The following pages are plots of the EDA data collected for the participants using the wireless sensor bands. Each figure consists of one participant's data where each subplot is the data collected for a day. The vertical red lines on the plots mark the times when a participant initiated a craving report. The second set of figures consists of EDA plots grouped by participant where each plot consists of the days of data collected for a participant plotted on the same graph.

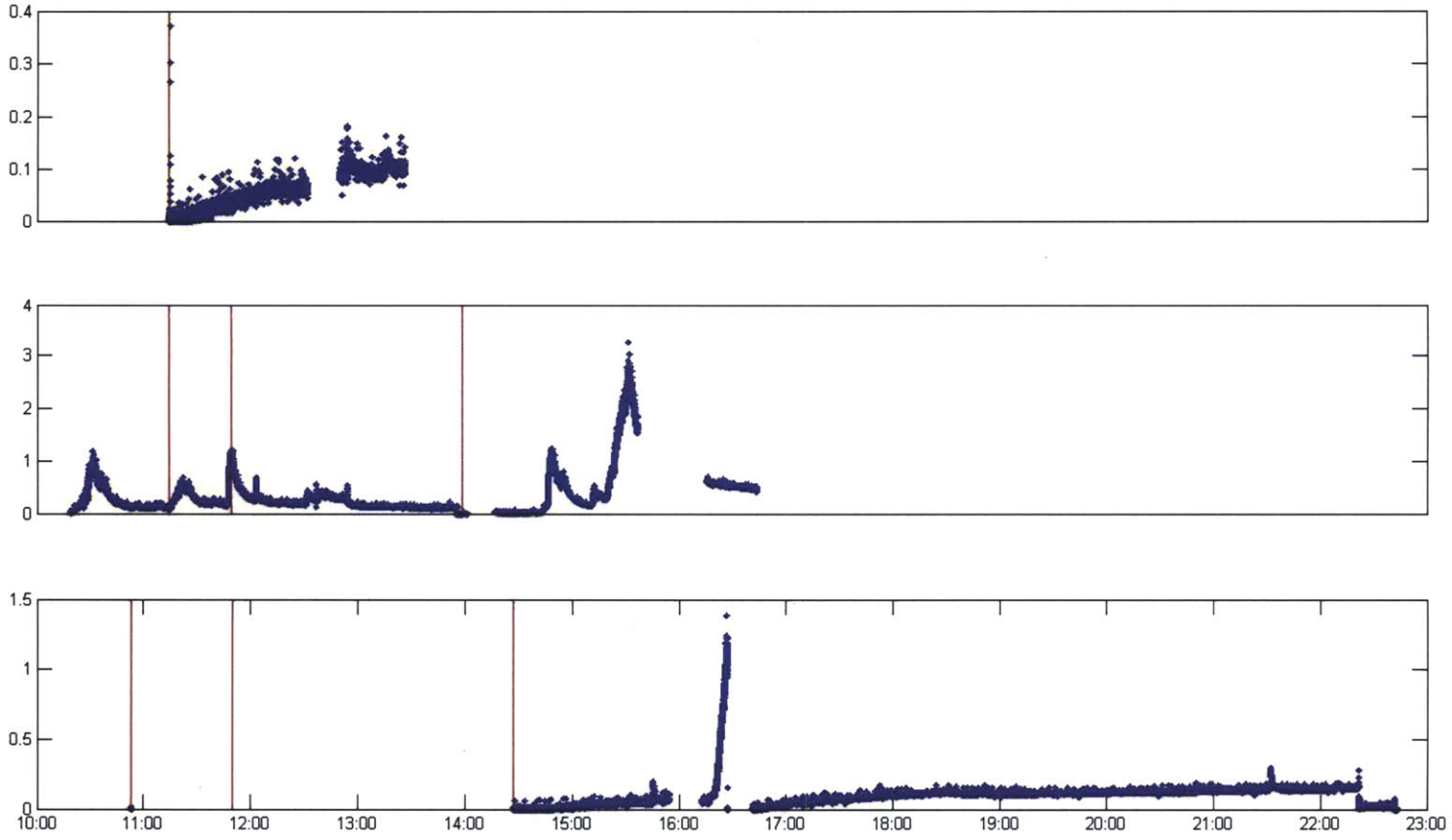
Participant 1 EDA Data

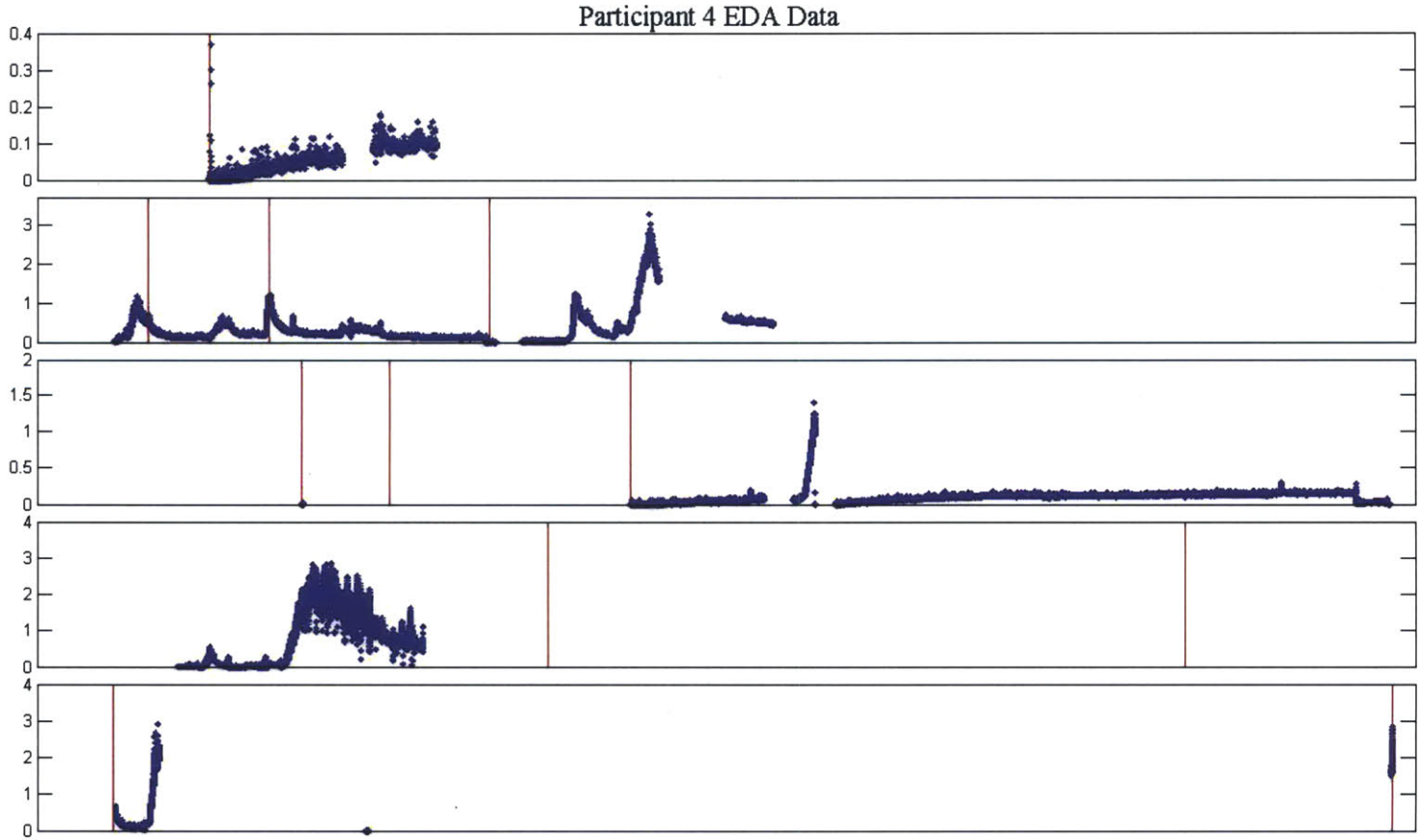


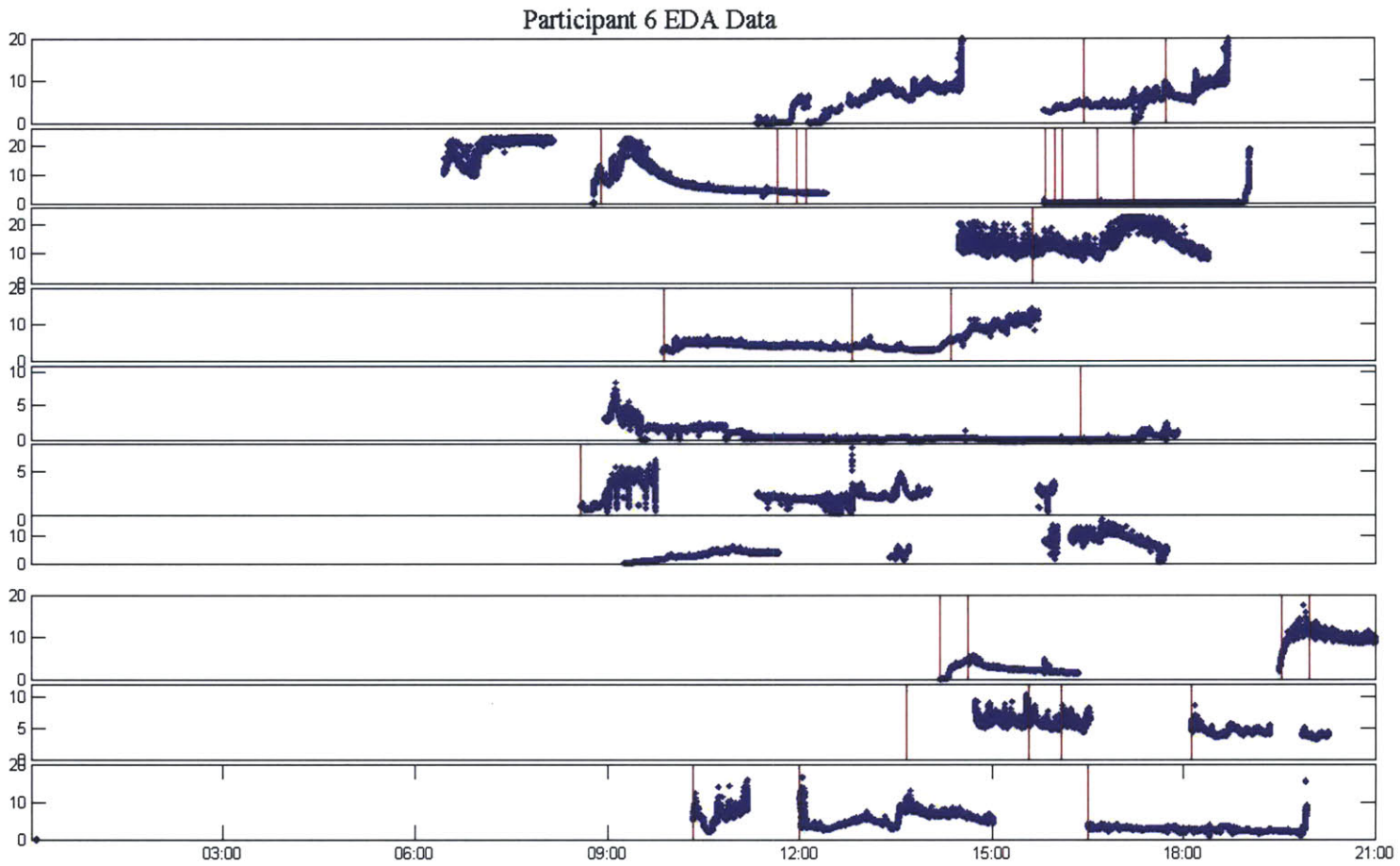
Participant 2 EDA Data



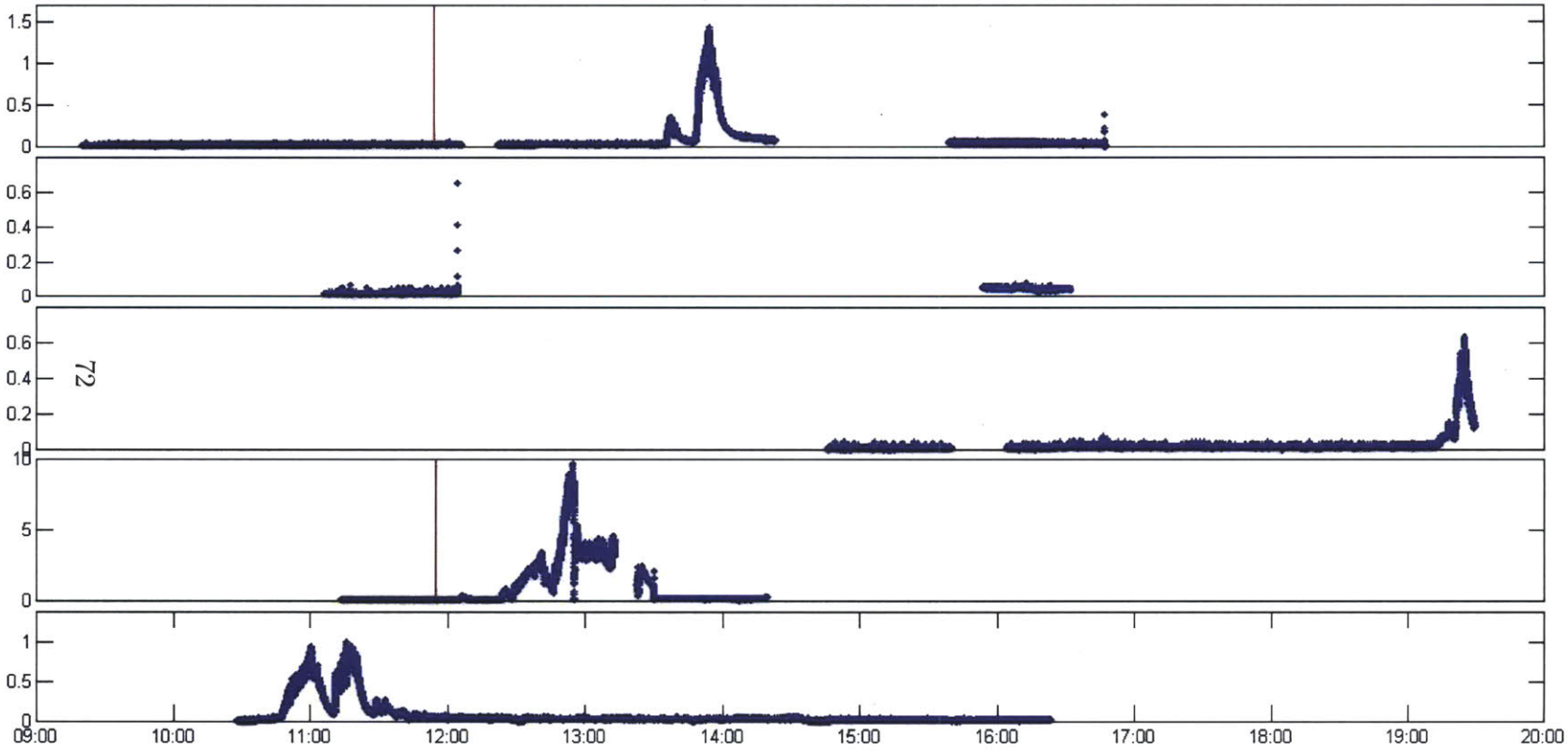
Participant 3 EDA Data

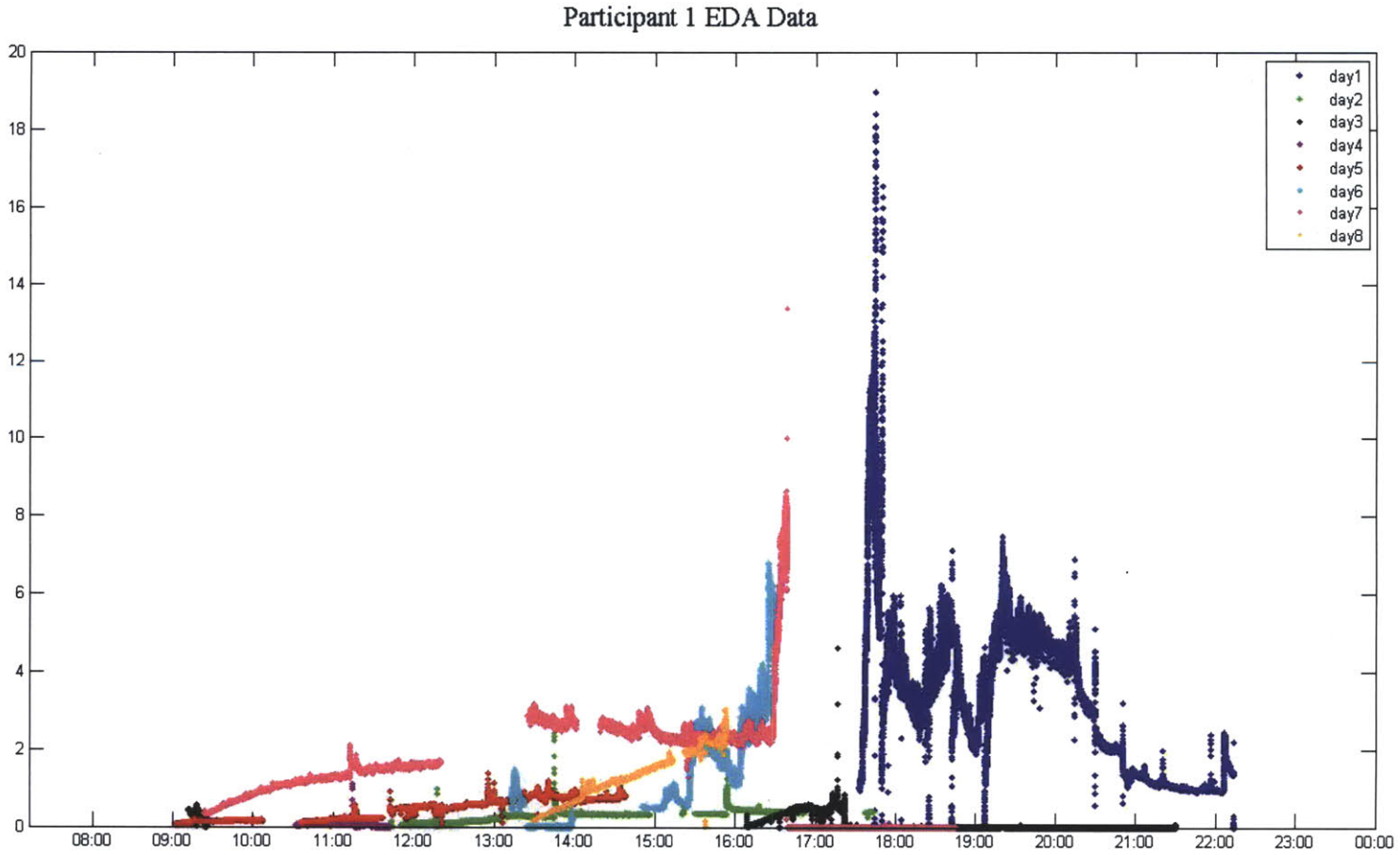



Participant 4 EDA Data
0.4
0.3
0.2
0.1
0
3
2
1
0
2
1.5
1
0.5
0
4
3
2
1
0
4
3
2
1
0


Participant 6 EDA Data
03:00
06:00
09:00
12:00
15:00
18:00
21:00

Participant 7 EDA Data




Participant 1 EDA Data
day1
day2
day3
day4
day5
day6
day7
day8
0
2
4
6
8
10
12
14
16
18
20
08:00
09:00
10:00
11:00
12:00
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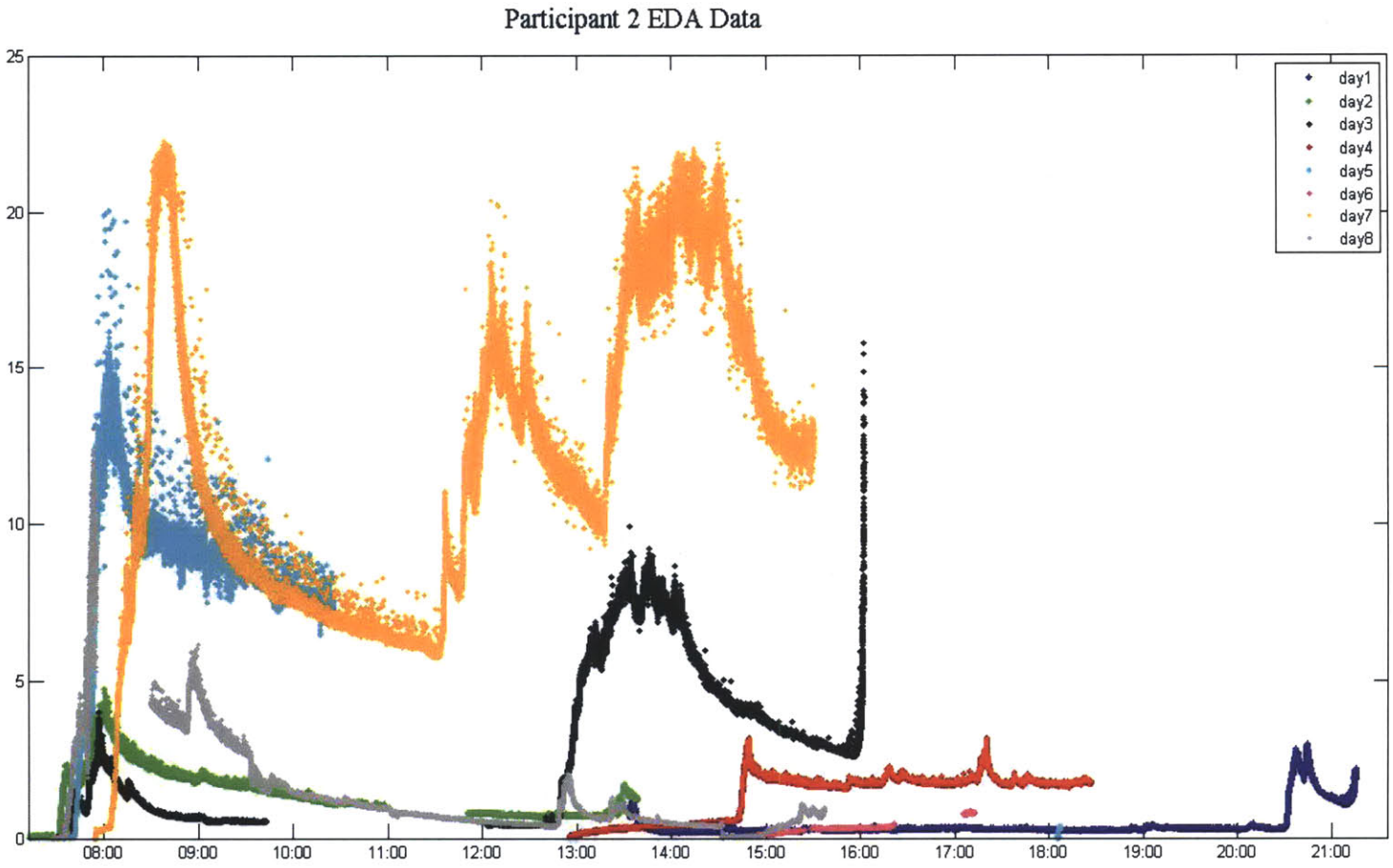
20:00
21:00
22:00
23:00
00:00


Participant 2 EDA Data
day1
day2
day3
day4
day5
day6
day7
day8
25
20
15
10
5
0
08:00
09:00
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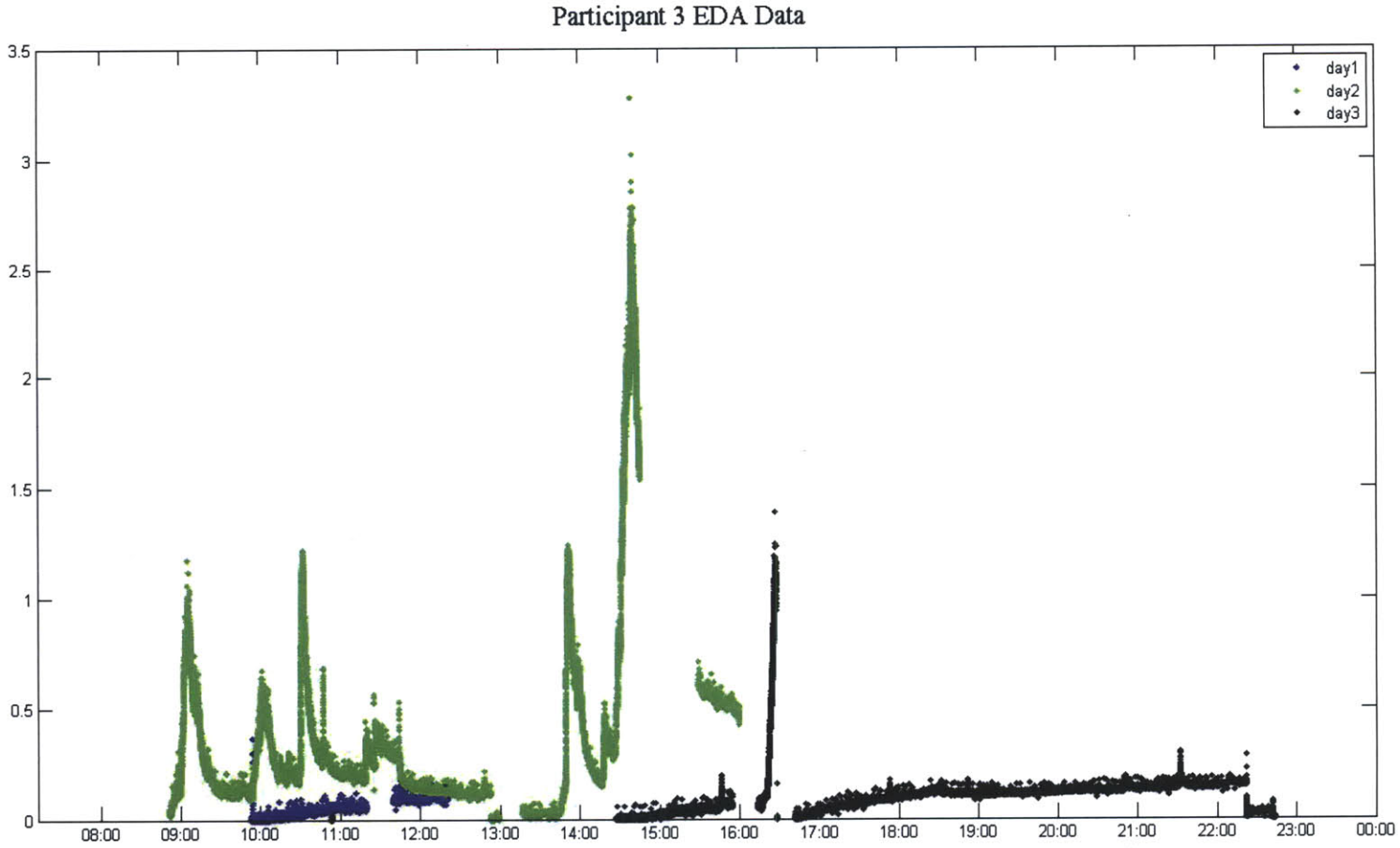
16:00
17:00
18:00
19:00
20:00
21:00


Participant 3 EDA Data
day1
day2
day3
3.5
3
2.5
2
1.5
1
0.5
0
08:00
09:00
10:00
11:00
12:00
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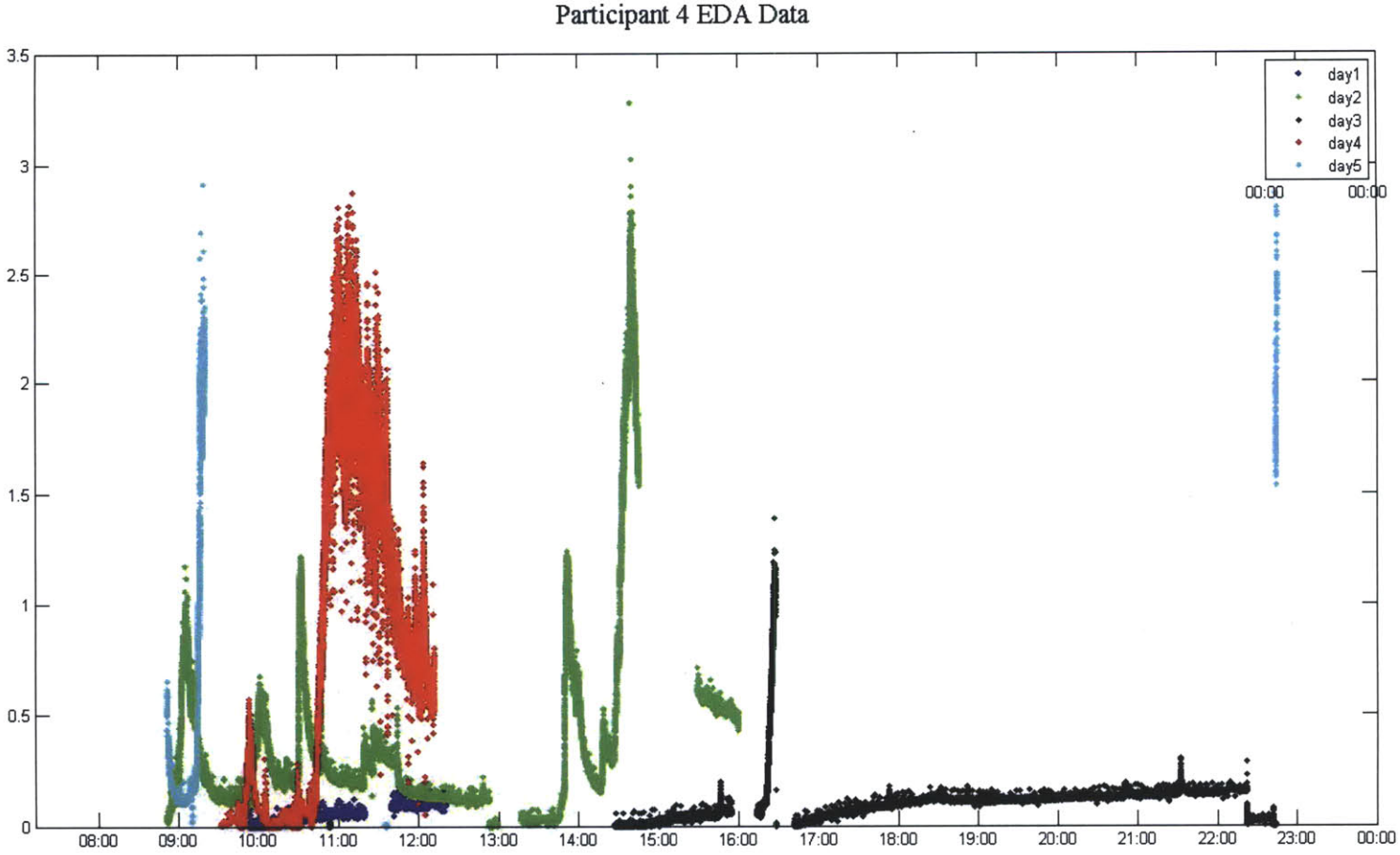
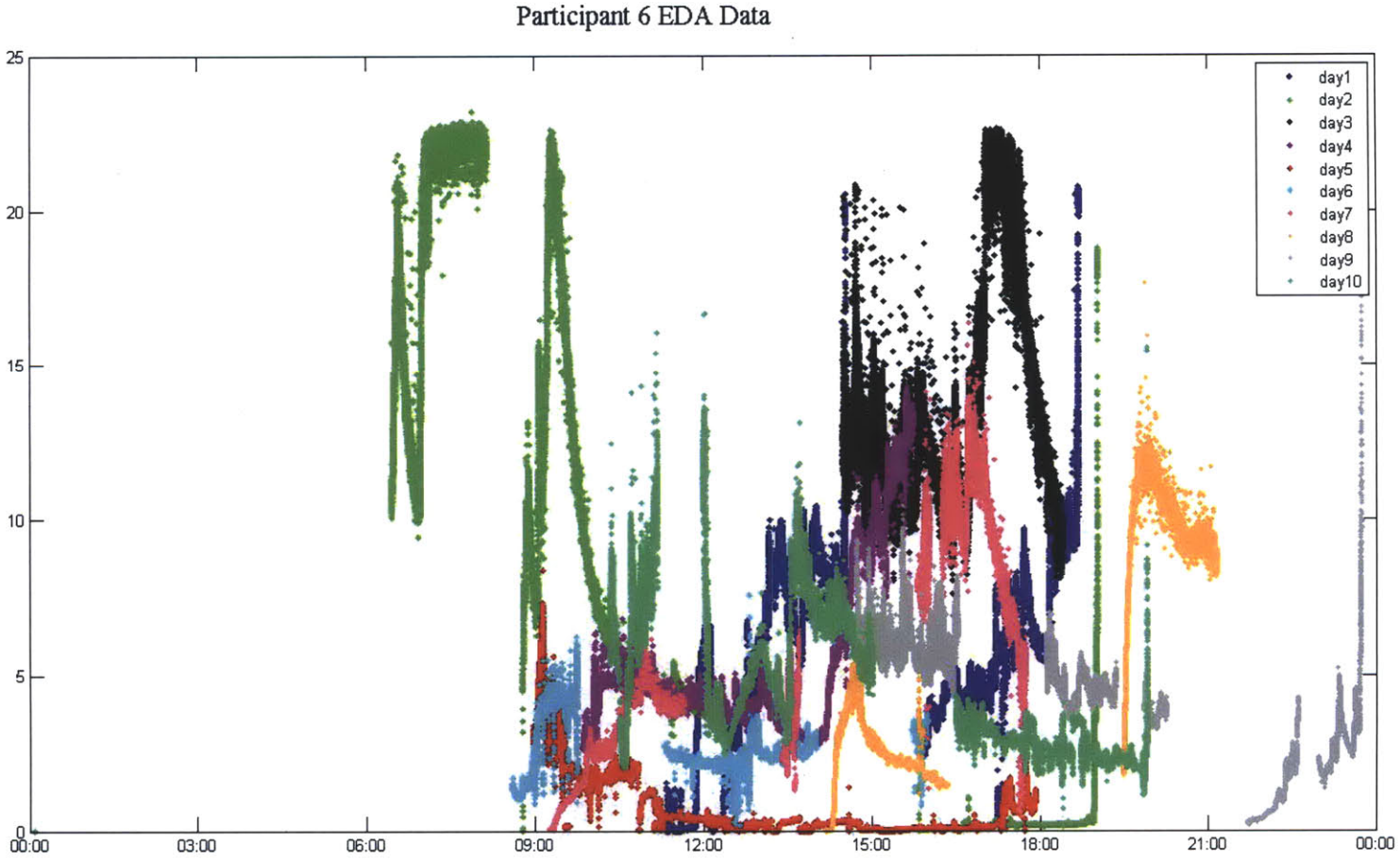
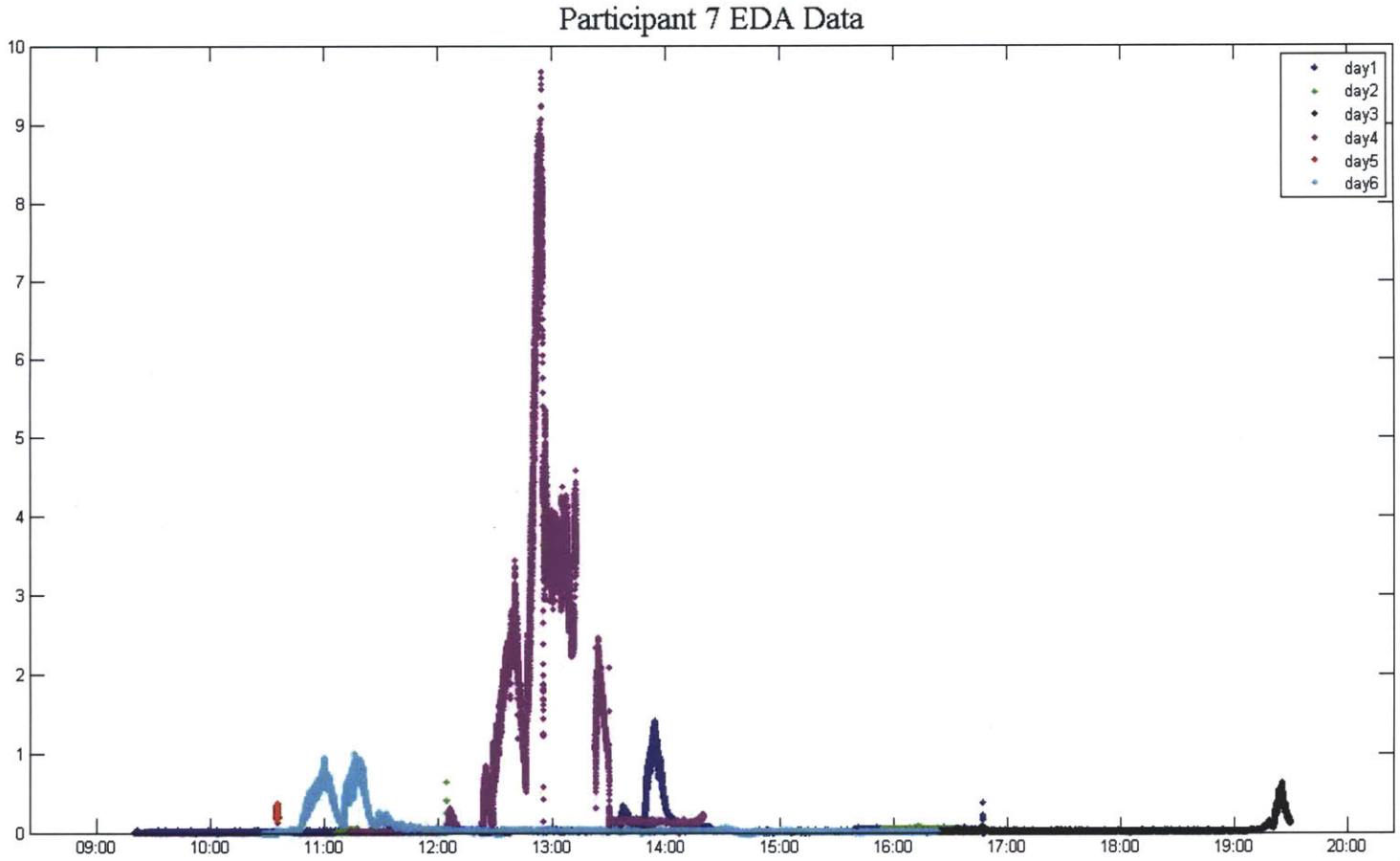
19:00
20:00
21:00
22:00
23:00
00:00


Participant 4 EDA Data
day1
day2
day3
day4
day5
3.5
3
2.5
2
1.5
1
0.5
0
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
00:00
00:00
00:00


Participant 6 EDA Data
25
20
15
10
5
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
day1
day2
day3
day4
day5
day6
day7
day8
day9
day10


Participant 7 EDA Data
day1
day2
day3
day4
day5
day6
0
1
2
3
4
5
6
7
8
9
10
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

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