



# Smartphone-Based Travel Experience Sampling and Behavior Intervention among Young Adults

## Final Report

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## EXECUTIVE SUMMARY

People spend significant time everyday traveling in cars, on foot, by bicycle and/or using public transit. Travel behavior directly influences individual health: Walking and bicycling contribute to moderate physical activity and different travel behaviors often come with varying well-being experiences.

In this study, we utilized the computing, communication, and sensing capabilities of smartphones and developed an Android phone application—named UbiActive—to collect real-time travel-related physical activity and psychological well-being data from phone users. We pilot tested the application on three types of Android phones including HTC Magic, MyTouch 4G, and Nexus S. Nexus S and HTC Magic were found to produce comparable physical activity outputs with the commercially available RT3 accelerometer.

We further applied UbiActive in a three-week field study to investigate the application's potential in tracking participants' travel-related physical activity, surveying participants travel-related psychological experiences, and reporting daily and weekly summaries on travel-related physical activity and psychological well-being back to the participants to promote healthier travel behavior. Twenty-three young adults were recruited at the University of Minnesota campus to participate in the study. They were randomized into two groups: an intervention group and a control group. Both groups were asked to install the UbiActive application on their phone and wear their phone on their right hip during all waking hours for three consecutive weeks. During the second week, participants in the intervention group were provided information on impacts of their travel behavior on physical activity and psychological well-being. Participants in the control group were not provided any information during the three weeks of field study. Seventeen of the 23 participants completed the three-week study, including 10 from the intervention group and 7 from the control group. After the field study, all participants were asked to complete a web-based exit survey that was comprised of questions about their general participation experience and specific concerns about the study design, the application, compliance requirements, and privacy issues.

Findings from the field study show that UbiActive has high potential in collecting travel-related physical activity and psychological experience data, yet limited effectiveness in behavior intervention. Findings from the exit survey show participants in general had a satisfying study experience, increased awareness of their travel behavior patterns and the associated health impacts, and difficulties in meeting some of the compliance requirements in the study, all of which provide useful insights into future improvement areas of the UbiActive application and the overall study design.

## CHAPTER 1: INTRODUCTION

The connections between transportation and population health in the United States are substantial and present. The U.S. has the lowest percentage of walking and bicycling trips (about 10%) and the highest driving mode share (about 85%) among wealthy countries (Ham, Macera et al. 2005; Hu, Reuscher et al. 2007). And according to the 2003 American Time Use Survey, Americans on average spent about 70 minutes in traffic every day, three times as much as twenty years ago. Given these unhealthy trends in travel behavior, the field would benefit from innovative data collection tools that help to investigate travel-related health impacts as well as well-designed behavior intervention studies that promote healthy travel behavior.

This research project develops a robust, smartphone-based application—UbiActive—for monitoring respondents' transportation routines, examining travel-related health impacts, and intervening against unhealthy travel behavior. Two major components of this research are (1) UbiActive prototype development and (2) a three-week field study that tests the viability of UbiActive for real-time data collection on travel-related health impacts and behavior intervention against unhealthy travel behavior.

Central to the UbiActive development is the utilization of various built-in smartphone sensors (e.g., GPS and accelerometer) as well as the application of the experience sampling method which allow participants to self-report their psychological experiences in real time. Taking advantage of the portability of smartphones, UbiActive records travel behavior, physical activity and well-being information at the trip level in real time, and thereby offers opportunities to investigate the physical activity and psychological well-being impacts of travel behavior.

The second component of this research features a three-week field study of real Android phone users to test the viability of UbiActive in tracking participants' travel-related physical activity, surveying participants' travel-related psychological experiences, and reporting daily and weekly summaries on travel-related physical activity and psychological well-being back to the participants to promote healthier travel behavior. A total of 23 Android phone users were recruited from the University of Minnesota campus, among which 12 were randomly assigned to the intervention group and the rest to the control group. The intervention group was provided information on impacts of their travel behavior on physical activity and psychological well-being. No information was provided to the control group. After the field study, all participants were asked to complete a web-based exit survey which comprised questions about their general participation experience and specific concerns about the study design, the application, compliance requirements, and privacy issues. Data from the three-week field study and the web-based exit survey were analyzed and implications of the analysis findings discussed.

As a final report, this document offers details of the research work that has been done from January 1, 2011 to March 1, 2012. The remainder of this report is organized as follows:

- **Chapter 2 – Literature Review.** Review of recent research on the connection between transportation and public health, as well as on applications of the experience sampling method (ESM) in this field.
- **Chapter 3 – UbiActive Application Development.** Detailed description of UbiActive application development and results from pilot testing of the application prototype.
- **Chapter 4 – Three-week Field Study.** Detailed description of the design and implementation of our three-week field study conducted in November 2011 as well as data analysis.
- **Chapter 5 – Conclusions and Future Direction.** Conclusions with a lookout to future direction.

## CHAPTER 2: LITERATURE REVIEW

### Connections between Transportation and Public Health

Key concepts in connecting transportation and population health include physical activity and well-being. Physical activity had been a somewhat understudied topic in transportation research. In recent years, however, walking and bicycling for daily transportation have been increasingly recognized as important sources of physical activity which present major opportunities for improving health among children, adolescents and adults. A substantial body of research has accumulated showing that certain aspects of the transportation infrastructure (e.g., public transit, greenways and trails, sidewalks and safe streets crossings, bicycle paths, and traffic calming devices) are associated with more walking and bicycling, greater physical activity and lower obesity rates (Brown and Werner 2007; Moudon, Lee et al. 2007). Beyond infrastructure investments, programs that raise awareness of health benefits of active transportation (e.g., the US Walk to School programs) are found to be promising in increasing physical activity and lead to improvements to individuals' health (Ward, Linnan et al. 2007; Eyster, Brownson et al. 2008; Fesperman, Evenson et al. 2008).

Well-being, which is often interchangeably used with "quality of life" in transportation literature, was less of an understudied topic in transportation when compared to physical activity. Early literature on well-being and transportation focuses on psychological effects of work commute. Evidence suggests that commuting stress is caused by a wide range of commute attributes, including commute length, road congestion, waiting time, unpredictability, crowding, etc. (Singer, Lundberg et al. 1978; Schaeffer, Street et al. 1988; Evans, Wener et al. 2002). In recent years, the field has made progress in examining well-being effects of transportation more globally using concepts such as "user satisfaction"—the question of how individuals are satisfied with travel, "happiness"—the question of how happy individual feel by using their current mode of transportation, and "travel liking"—the question of how much individuals like to travel (Ory and Mokhtarian ; Friman, Edvardsson et al. 2001; Friman and Gärling 2001).

Despite substantial progress made in documenting physical activity and well-being effects of travel behavior, two limitations exists. First, studies examining travel-related physical activity impacts are often separate ones from those examining travel-related well-being effects. There are major disconnect between the two bodies of literature, as well as difficulties in measuring the total impact of travel behavior on health, including both the physical and mental aspects. Second, while research on travel-related physical activity has begun using new technologies (e.g., accelerometers and pedometers) that enable real-time data collection, research on travel-related well-being has largely relied upon paper and pencil techniques which ask respondents to report in retrospect their travel behavior and general well-being status in previous day(s). Few studies collect real-time data on well-being at the time of travel or immediately after a completed trip. Almost no research to date is able to capture contemporaneous, time-based fluctuations in the quality of daily travel experiences.

In this research, we apply ESM—a data collection technique originally developed in 1980s in social psychology—to address the above limitations. ESM often asks participants to report their psychological experiences or well-being status immediately after the studied event occurred (Brandstätter 1983; Csikszentmihalyi and Larson 1987), as a way to reduce recall bias and capture psychological status associated with the studied event more accurately. In the following section, we briefly review previous ESM research efforts.

## **Experience Sampling Method**

In early applications of ESM, researchers often relied upon telephones, pagers, beepers or alarm clocks to either remind participants to keep a diary of the studied events or signal participants to answer a set of questions on a pre-designed questionnaire booklet (Brandstätter 1983; Csikszentmihalyi and Larson 1987). The timeline of reminders and signals were often randomly scheduled and rarely occurred at the times they supposed to occur, i.e., immediately after the study event.

In recent years, the popularity of portable devices has led to a series of ESM advancements that realize electronic data collection and improve the timing of signals and reminders for participants to report their psychological status immediately after each studied event (Barrett and Barrett 2001; Consolvo and Walker 2003; Intille, Rondoni et al. 2003; Raento, Oulasvirta et al. 2005; Sohn, Griswold et al. 2006; Khan, Markopoulos et al. 2008; Froehlich, Dillahunt et al. 2009; Kukkonen, Lagerspetz et al. 2009; Hicks, Ramanathan et al. 2010). For instance, Intille et.al (2003) advanced ESM by employing a PDA with sensors embedded, named the Context-Aware Experience Sampling (CAES) tool (Intille, Rondoni et al. 2003). By relying upon sensor data, CAES is able to trigger self-report surveys at specific time points of research interests based upon detected context-information. A recent extension of CAES is CAESSA (Context-Aware Experience Sampling Study Authoring) , a visual authoring toolkit (Fetter, Schirmer et al. 2011). This new extension broadens the user group of CAES by allowing researchers to select sensors and design questionnaires using a graphic visual interface rather than using java programming codes. Lately, MyExperience developed by Froehlich et.al (2007) is considered as one of the most comprehensive ESM platforms (Froehlich, Chen et al. 2007). MyExperience is designed to run on personal mobile devices to collect real time data on people's contextual settings, thoughts, reflections, moods, and feelings. MyExperience gathers quantitative data on contextual settings (e.g., temperature and location) through automatic sensing. It further gathers in situ qualitative self-report data via event-driven action-trigger-action architecture.

Despite the recent advancement in ESM, ESM has rarely been applied to travel behavior research. One exception is a study that used MyExperience to explore personal place preference (Froehlich, Chen et al. 2006). The study linked self-reported ratings of a place to visit frequency and travel time associated with the place, and found higher preference ratings for bars, cafes and restaurants to be associated with more frequent visits and longer travel time to these places. In

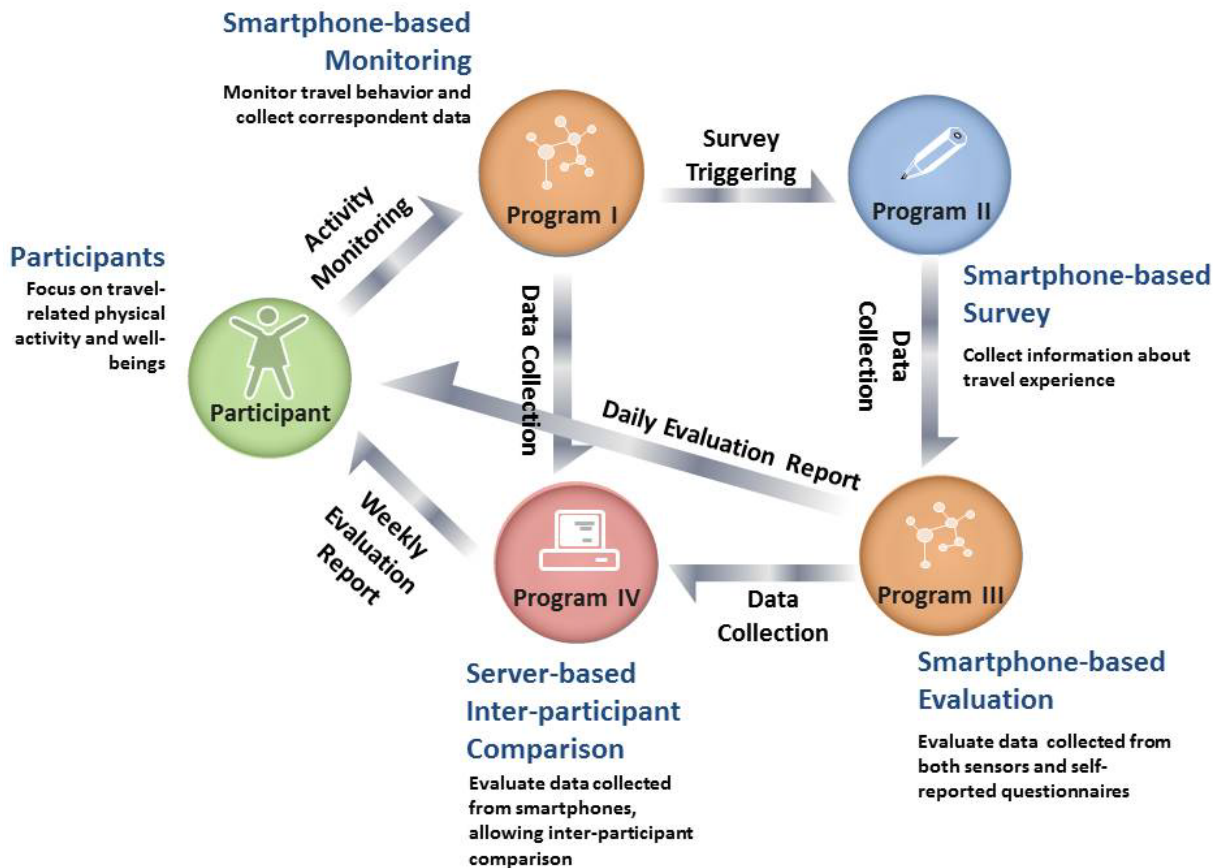
another study, Froehlich et al. developed a new prototype “UbiGreen” based upon MyExperience. UbiGreen asks respondents to self-report their travel behavior, and based upon the reported data, provides respondents visual feedback on the environmental impacts of their travel behavior (Froehlich, Dillahunt et al. 2009). The study also features a field testing which demonstrated the viability of UbiGreen in intervening people’s travel behavior and promoting green transportation. Fetter et al. installed CAESSA in train commuters’ laptops to study their laptop work behavior during the train commute (Fetter, Schirmer et al. 2011). Although travel behavior was not their main focus, Fetter et al (2011) addressed two travel-related questions: (1) whether CAESSA can detect location changes; (2) whether participants can concentrate on their work during crowded train commutes. Their study successfully demonstrated the capability of mobile device-based ESM to track location changes and transit trips.

To summarize, there are limited applications of mobile phone-based ESM in studying travel behavior. To date, no research has used these advanced ESM tools for examining health impacts of travel behavior. This research presents a direct response to this knowledge gap by developing a phone-based ESM application named UbiActive, which semi-automatically senses and collects momentary information about travel-related physical activity and travel-related psychological well-being.



## CHAPTER 3: UBIACTIVE APPLICATION DEVELOPMENT

We develop UbiActive based upon Android systems. Unlike Apple's *IPhones* and Microsoft's *Palm series*, Android phones offer open development platform and a diverse set of built-in hardware sensors including orientation, GPS, accelerometer, light, magnetic field, and temperature sensors, which are better designed to detect human movements and physical activity intensity. Our UbiActive application includes three local programs based on smartphones and one inter-participant comparison program based on a remote system server. The three smartphone-based local programs include a monitoring program, a context-triggered survey program, and an evaluation program as shown in Figure 3.1.



**FIGURE 3.1 Framework of UbiActive Application Prototype**

The monitoring program in UbiActive (Program I) detects movements by continuously monitoring and recording XY coordinates and moving speed of smartphone users. Based upon the recorded location and speed data, the monitoring program determines start and end time of each trip, as well as trip duration and distance. Given this study focuses on physical activity and psychological well-being effects of daily travel routines, UbiActive is designed to record



information only for trips longer than 10 minutes to avoid extremely short trips such as movements within the same building (e.g., walking to the cafeteria or restroom) as these short trips have limited relevance to daily travel routines. Further, Program I utilizes the built-in accelerometer in smartphones to record acceleration outputs (unit:  $\text{m/sec}^2$ ) along three orthogonal axes (x, y, and z), and based upon acceleration outputs, determines physical activity intensity and further estimates physical activity-related energy expenditures (e.g., calories burned).

The context-triggered survey program (Program II) automatically triggers a short survey on the smartphone upon completion of each trip conducted by the participant. The program will display a series of trip questions on the phone screen, including questions about the start and end time, purpose, companionship, mode, secondary activities, and psychological experience/well-being during the trip. Each survey action is anticipated to take 2-3 minutes.

The evaluation program (Program III) summarizes both monitoring and self-report survey data, and calculates daily and weekly physical activity amount and average well-being status that are related to travel for each participant in the intervention group. The calculations are conducted locally on participants' smartphones, and calculation results are displayed on smartphone for each participant in the intervention group.

Finally, the system server-based inter-participant comparison program (Program IV) operates on a remote system server and collects monitoring and survey data from all the participants in the intervention group. The program conducts weekly inter-participant comparison to rank each participant in terms of their physical activity amount and well-being status. The rankings are sent to the smartphones of the participants in the intervention group for their information and to encourage inter-participant competition and promote healthy travel behavior changes. The following text provides additional details on each of the four UbiActive programs.

## **Program I: Smartphone-Based Monitoring**

### *Program Design and Development*

Program I utilizes three built-in sensors including a 3-dimensional accelerometer, 3-dimensional magnetic sensor, and GPS. These three sensors provide data on smartphone user's location, movement time, speed, acceleration, and orientation, all of which help to derive travel distance, duration, and mode of each trip as well as to measure physical activity intensity, duration, and the associated energy expenditures.

### Smartphone Sensing

Most smartphones have a 3-dimensional accelerometer (typical full-scale of  $\pm 2 \sim 8 \text{ g}$ ,  $g=9.8 \text{ m/s}^2$ ) and a 3-dimensional magnetic sensor (typical full-scale of  $\pm 1.3 \sim 8.1 \text{ gauss}$ ) embedded,

which can be used to determine the intensity of physical activity and movement orientation. Further, MEMS (Micro-Electro-Mechanical Systems) based geo-magnetic model in smartphones allows advanced navigation and location-based services by integrating high-resolution three-axis sensing of linear and magnetic motion. GPS receiver embedded in the smartphone provides the user's location data and information on travel distance. In this research, the monitoring program (Program I) is designed that, when the phone boots up after installing the program, the program automatically starts and always runs in the background. The program records sensing data from accelerometer, magnetic sensor, and GPS receiver. Sampling frequency of the accelerometer and magnetic sensor is configured to 1 Hz (one sampling per second). The GPS data sampling frequency is configured to every 30 seconds and the minimum distance interval for movement notification is 10 meters.

Physical activity is measured by activity count (unit:  $m/s^2$ ) which is computed using the 3-dimensional accelerometer outputs. If the built-in-accelerometer in a phone offers linear acceleration outputs, we use the formula proposed by Bouten et al. (1997) (Bouten, Koekkoek et al. 1997) to calculate the activity count. Currently, almost all the Android phones with an Android version of 2.3 or higher produce linear acceleration outputs.

$$Activity\ Count = \int_{t_0}^{t_0+T} |a_x| dt + \int_{t_0}^{t_0+T} |a_y| dt + \int_{t_0}^{t_0+T} |a_z| dt \quad (Equation\ 1)$$

Where,  $a_x$ ,  $a_y$ ,  $a_z$  are the linear acceleration measurements in x, y, and z directions.

Nonetheless, many smartphones in the present market only produce raw acceleration outputs instead of linear acceleration outputs. Raw acceleration outputs contain the gravity component. For those phones, we employ Equation 2 as shown below to remove the gravity component from the activity count calculation.

$$Activity\ Count = \int_{t_0}^{t_0+T} |a_x'| dt + \int_{t_0}^{t_0+T} |a_y'| dt + \int_{t_0}^{t_0+T} |a_z'| dt - g \quad (Equation\ 2)$$

Where,  $a_x'$ ,  $a_y'$ ,  $a_z'$  are the raw acceleration measurements in x, y, and z directions.  $g$  is the gravity force ( $g=9.8\ m/s^2$ ).

### Energy Expenditures Calculation

In order to convert activity count data into energy expenditures, we calibrate our activity count data with energy expenditure data obtained from two other sources: (1) the commercially available RT3 accelerometer outputs; and (2) the Metabolic Equivalent (MET) method. RT3 is a tri-axial accelerometer commercially available from StayHealthy, Inc. This accelerometer has been used by many researchers for measuring physical activity (Powell, Jones et al. 2003; Rowlands, Thomas et al. 2004). It provides physical activity data in the unit of both activity count and caloric expenditure. As for the calibration, to ensure that activity counts generated by smartphones and caloric energy expenditure outputs generated by RT3 measure the same activity, field research assistants were asked to wear a RT3 unit and a Smartphone side by side on the right hip when conducting physical activity. The comparable RT3 energy expenditure

outputs and smartphone accelerometer outputs were then compared and used to calculate the RT3 scaling factor as shown below.

$$RT3 \text{ Scaling Factor}(kcal/count) = \frac{RT3 \text{ Energy Expenditure}(kcal/min)}{Smartphone \text{ Counts}(count/min)} \quad (Equation 3)$$

Derived from field experiments, this scaling factor is then used to convert activity count data from smartphones into energy expenditure data in calories (kcal) per min. In this research, we calculate the cumulative energy expenditure per person per day using this method. We further divide the daily energy expenditure into travel-related and non-travel related expenditures. Energy expenditures associated with activities with corresponding travel speed higher than 1.5 m/s are considered as energy expenditures associated with travel-related physical activity. Although the average walking speed is 1.4 m/s (Lundgren-Lindquist, Aniansson et al. 1983; Hirasaki, Moore et al. 1999), given that all of our participants are young adults, we chose a slightly higher threshold.

Another way to convert activity count data into caloric energy expenditures is the MET method. MET, defined as the ratio of the work metabolic rate to the resting metabolic rate, is a widely used physiological concept that represents the energy cost of physical activity. A MET value of one is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly. A few MET values of different physical activity are listed in Table 3.1. By using the MET values associated with different activities and the smartphone-generated activity counts associated with the corresponding activities, we can derive another scaling factor as shown below.

$$MET \text{ Energy Expenditure}(kcal/min) = \frac{MET(kcal \cdot kg^{-1} \cdot hour^{-1}) \times Body \text{ Weight}(kg)}{60(min \cdot hour^{-1})} \quad (Equation 4)$$

$$MET \text{ Scaling Factor}(kcal/count) = \frac{MET \text{ Energy Expenditure}(kcal/min)}{Smartphone \text{ Counts}(count/min)} \quad (Equation 5)$$

**TABLE 3.1 Sample Metabolic Equivalent (MET) Values**

<b>Physical Activity</b>	<b>MET</b>
Riding in a car or truck	1
Automobile or light truck (not a semi) driving	2
Food shopping with or without a grocery cart, standing or walking	2.3
Walking from house, to car or bus, from car or bus to go places, from car or bus to and from the worksite	2.5
Walking, 2.5 mph (4 km/h)	2.9
Bicycling, <10 mph (16 km/h), leisure, to work or for pleasure	4
Jogging, general	7
Calisthenics (e.g. pushups, sit-ups, pull-ups, jumping jacks), heavy, vigorous effort	8

Data Source: [http://en.wikipedia.org/wiki/Metabolic\\_equivalent](http://en.wikipedia.org/wiki/Metabolic_equivalent);  
<http://riskfactor.cancer.gov/tools/atus-met/met.php>

A disadvantage of the MET method is that it requires exactly knowledge of activity types. This method is not used in this research but mentioned here for reference purposes.

### *Pilot Testing*

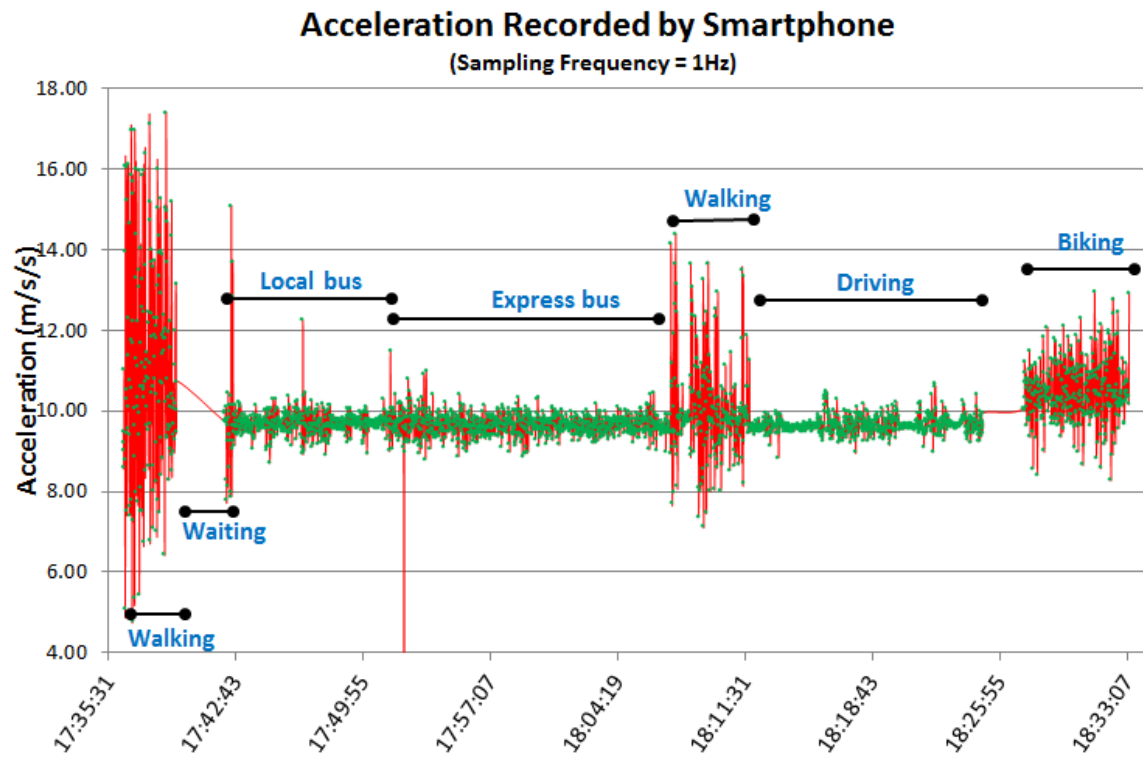
#### Auto Tracing

We conducted experiments with MyTouch 4G, Nexus S, and HTC Magic phones to check the quality of smartphone sensor outputs, especially outputs from the built-in accelerometer. Both HTC Magic and Nexus S phones provide good sensory outputs from the accelerometers. However, the MyTouch phone, running on Android OS ver.2.2.1, deactivates the internal sensory system when the touch screen is dimmed. This feature prohibits us from continuously collecting accelerometer and GPS data. To avoid this problem, we decided to recruit Android phone users with Android OS version earlier than 2.0 or later than 2.3 for our later field study.

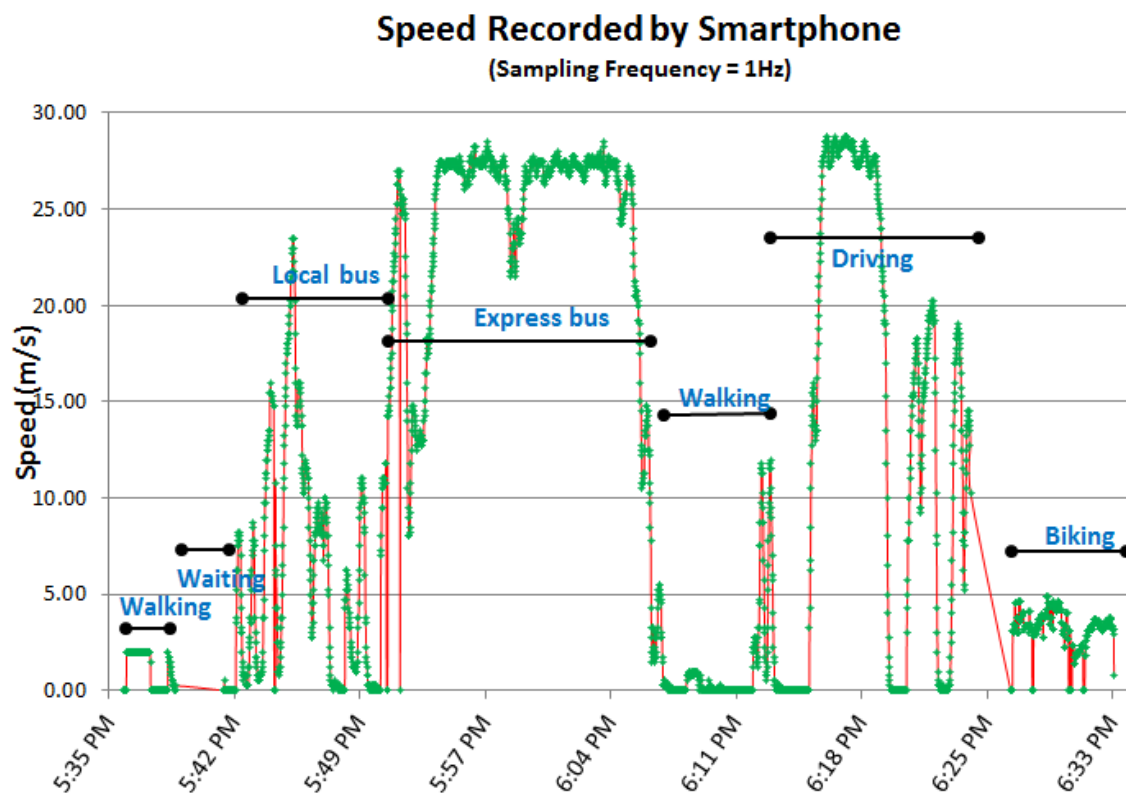
#### Travel Mode Detection

Experiments were conducted to test how accurate the UbiActive application could detect travel mode. Figures 3.2 and 3.3 respectively show acceleration and speed data of an experiment trip conducted on March 16, 2011. The experiment trip included walking, biking, transit and driving mode, and was recorded using a HTC Magic phone. As shown in Figures 3.2 and 3.3, it is not difficult to distinguish walking and biking from the other modes. Trip data from walking and biking modes have larger acceleration variations and lower travel speed (the speed of biking is larger than that of walking) as compared to those from the transit and driving mode. The speed and acceleration profiles from transit and driving on arterial road are less distinguishable. To address this issue, we require participants to self-report in order all the modes they used in each

trip in the phone-based after-trip survey section. The final determination of travel modes relies upon the combination of speed profile, acceleration data, and self-reported information.



**FIGURE 3.2 Acceleration Outputs from HTC Magic**



**FIGURE 3.3** Speed Outputs from HTC Magic

- Energy Expenditure Estimation

A series of testing was conducted to estimate scaling factors to be used to convert smartphone accelerometer data to caloric energy expenditures. Particularly, the scaling factors of 4 physical activities (i.e., walking, bicycling, driving and riding a bus) are estimated from four testing trips as shown in Table 3.2. The first testing trip is by walking (4 km/h); the second is a 19-minute long trip which is consist of 4-minute walking from home to bus station, 5-minute waiting (standing), and 10-minute bus riding; the third is a driving trip, and the last trip is by biking.

As discussed in the previous program design and development section, the scaling factors could be calculated through two methods: RT3 calibration and MET method. In terms of RT3 calibration, Table 3.2 lists the estimated activity counts (count/min) from HTC Magic phone (estimation is based upon Equation 2) and energy expenditure outputs (RT3 EE, kcal/min) directly produced by from RT3. Using equation 3, the scaling factor could be easily computed as the ratio of RT3 energy expenditure and HTC counts. As shown in Table 3.2, the computed RT3 scaling factors range from 0.011 to 0.021. As for the MET method, there are two steps to calculate the scaling factors. First, we calculate energy expenditure  $e$ (MET EE, kcal/min) from the corresponding MET (kcal/kg/hr) using Equation 4. Then, we calculate the scaling factor by

dividing the MET energy expenditure by the HTC counts using Equation 5. The obtained MET scaling factors range from 0.009 to 0.018.

**TABLE 3.2 Energy Expenditure Scaling Factor Computation Example**

	Activity Duration	HTC Count	RT3 Method		MET Method			
			RT3 EE	RT3 Scale	MET	Body Weight	MET EE	RT3 Scale
			min	count/min	kcal/min	kcal/count	kcal/kg/hr	kg
<b>Walking</b>	9	392	8.2	<b>0.0210</b>	2.9	72.6	3.5	<b>0.0090</b>
<b>Bus</b>	19	196	3.2	<b>0.0162</b>	1.7*	72.6	2.0	<b>0.0102</b>
<b>Drive</b>	17	263	3.0	<b>0.0113</b>	2	72.6	2.4	<b>0.0092</b>
<b>Biking &lt; 10 mph</b>	25	180	3.0	<b>0.0168</b>	4	49.0	3.3	<b>0.0182</b>

Note: All MET values are derived from Table 3.1 based upon activity types. The MET value of the bus trip involves aggregating several trip components, including 4-minute walking from home to bus station with a MET value of 2.5 kcal/kg/hour, 5-minute waiting (standing) with a MET value of 2.3 kcal/kg/hour, and 10-minute bus riding with a MET value of 1 kcal/kg/hour, all of which result in an average MET value of 1.7 kcal/kg/hour.

## **Program II: Smartphone-Based Experience Survey**

### *Program Design and Development*

UbiActive collects self-reported travel experience from participants through triggering survey actions on the smartphone immediately after a trip is detected. Two counters are used to determine the occurrence of a valid trip (trip with duration longer than 10 minutes) and then trigger a phone-based survey: counter A is for judging the start of a trip and counter B is for determining the end of a trip. As mentioned in the previous section, UbiActive configures GPS sampling and location updating to every 30 seconds. If after 30seconds the detected movement is larger than 30 meters, an event of “location change” would be reported to counter A, at that time counter A whose default value is 0 would automatically add one. The threshold of 30 meters is determined by two reasons. First, according to the average walking speed of 1.4m/s (Lundgren-Lindquist, Aniansson et al. 1983; Hirasaki, Moore et al. 1999), the average 30-second movement by walking is around 42 meters. Therefore, choosing 30 meters per 30 second as a threshold ensures detection of movements by most travel modes. Second, GPS receivers usually have positioning errors, therefore, it is possible that the user is stationary, but GPS error leads to incorrect records of location change. Our testing experience shows that a 30-meter window helps to avoid incorrect records of location change. When counter A reaches 20 counts, indicating there is a 10-minute continuous movement, a valid trip is considered to be happening.

After a valid trip is considered started, counter B starts working to determine when the trip ends. Every 30 seconds, if no “location change” is updated, count B whose default value is also 0 will automatically add 1. When counter B reaches 10 counts, meaning there is no significant movement for 5 minutes, the trip is considered end and counter A is reset to 0. Before the end of trip is determined, once there is a single event of “location change” reported, counter B will be reset to 0 and continue counting. Each survey action is triggered immediately after the end of a valid trip is determined, which we infer observing stationary for a period of 5 minutes. Most times, there are some intervals within trips during which people are stationary, for instance, waiting for bus and waiting for traffic light. Therefore we use being stationary for 5 minutes as the threshold to determine whether participants finish their trips. This threshold is same as what Welbourne et.al. (2005) use in their research (Welbourne, Lester et al. 2005). Although some research uses 10 minutes as threshold (Froehlich, Chen et al. 2006), there is a concern that a longer threshold would have higher chances to interrupt people’s after-trip activity: If we trigger the survey 10 minutes after a participant finishes his/her trip, the participant is very likely already in the middle of another activity, like taking class or working, thus may not be available to answer the survey.

Appendix A shows a flowchart of the survey triggering process. Each survey action occurs with beeper and vibration alerts. The survey first asks participant to confirm whether he/she has completed a trip. It is possible that the detected movement is not a trip from the transportation standpoint, for example, participants might be jogging. An answer option of “it is not a valid trip” is provided for such cases. If the participant indicates no valid trip is conducted, the survey action ends. Also, if the participant indicates the trip has not finished yet, the survey action ends as well. If there is a valid trip confirmed finished, the participant is further asked whether he/she is available to complete a survey. If yes, a series of questions will follow. If not, the participant is asked “when do you prefer to answer the survey?” and then UbiActive re-triggers the survey at the time the participant chooses. UbiActive allows 5 minutes to respond. If a prompt is missed, UbiActive sends a second prompt to the participant 5 minutes later. If the participant misses the second prompt, the survey is recorded as missing. The 5-minute waiting time threshold is selected based upon the existing literature (Shiffman 2000; Barrett and Barrett 2001). In case UbiActive misses a valid trip and fails to automatically trigger an after-trip survey, UbiActive is designed to allow participants to self-trigger the survey by simply clicking an icon displayed on the home screen of their phones.

Each survey includes two sets of questions as shown in Appendix B. The first set (Questions 0-3) asks about basic trip information including start and end time, trip purpose, all travel modes used in order, accompany and secondary activities. The second set (Questions 4-7) asks about travel psychological experience/wellbeing as shown below.

- Question 4: Do you agree with the statement “I was satisfied with this trip”?
- Question 5: Do you agree with the statement “This trip made me feel good”?



- Question 6: Do you agree with the statement “When I think of this trip the positive aspects outweigh the negative”?
- Question 7: In general, how happy were you during this trip?

Questions 4-6 are developed based upon the Satisfaction with Travel Scale (STS) (Bergstad, Gamble et al. 2010). STS was developed specifically to measure satisfaction with travel without including any other daily activities, which fits closely with our research objective. Question 7 is derived from the question that the World Values Survey used to measure people’s overall happiness (Inglehart, Puranen et al. 2005). There are multiple-item scales to measure cognitive subject well-being (Diener, Emmons et al. 1985; Watson, Clark et al. 1988; Västfjäll, Friman et al. 2002), this single-item question is used to reduce respondent burden. Appendix C summarizes the research work we reviewed containing subjective well-being (SWB) questions.

### *Pilot Testing*

Pilot testing was performed to check whether survey actions can be triggered properly. Research assistants were asked to wear a smartphone with UbiActive application installed for 24 hours, and keep a diary to record the time when they receive triggered surveys. The diary for an example testing day is shown in Table 3.3. In this particular day, four trips have been conducted, and UbiActive was able to properly detect three trips. Post-experiment data analysis shows that the error associated with one of the trips is mainly caused by the GPS signal strength and multipath noises from the environment. We also found that, due to GPS signal noises, the UbiActive application creates false survey triggering when the GPS samples position every second. The sampling rate was later adjusted to every minute but the per-minute update was found to generate a significant number of misses on completed trip detection. The GPS position update is eventually configured to 30-second to reduce battery use and false survey prompts.

**TABLE 3.3 Pilot Testing of After-Trip Survey Triggering Accuracy**

What <b>TIME</b> did you start and end each trip?		<b>HOW</b> did you Travel?	<b>WHEN</b> did you receive the first prompt?	Remark
Start at:	Arrived at:			
7:48 p.m.	8: 38 p.m.	car, bus, walk	8:45 p.m.	Trip detected
4:46 p.m.	6: 12 p.m.	walk, bus, car	6: 15 p.m.	Trip detected
7:07 p.m.	7:28 p.m.	car	7:20 p.m.	Incorrect prompt
9:25 p.m.	9:50 p.m.	car	9:55 p.m.	Trip detected

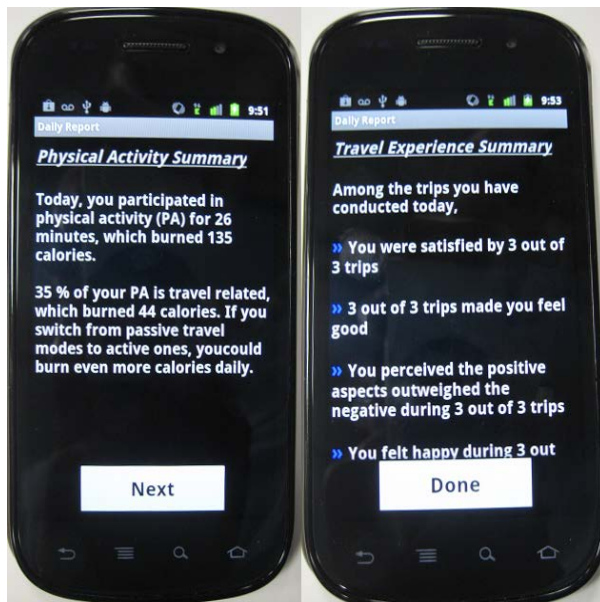
## Program III: Smartphone-Based Evaluation

### *Program Design and Development*

Program III summarizes the real-time collected data and provides daily reports to participants. Since all the sensor-based logging data as well as the triggered survey data are automatically stored to the local SQLite database running on the android phone (Froehlich, Chen et al. 2007), data processing for daily report is able to be conducted locally on the android phone. Daily report summarizes the following information: (1) total duration of physical activity in the past day; (2) total duration of physical activity related to travel; (3) calories burned by travel and non-travel physical activity; (4) travel experience/well-being ratings. Daily reports are scheduled to be provided to participants at 10pm every day.

### *Pilot Testing*

A pilot testing of the daily evaluation program was performed by wearing a Smartphone with the UbiActive application for three weeks. The test shows proper daily report is provided every day at 10 pm in the second week as programmed. Both physical activity and travel experience summaries were properly displayed on the screen of the testing smartphone (as shown in Figure 3.4).



**FIGURE 3.4** Screenshots Showing Daily Report Example

## **Program IV: System Server-Based Inter-Participant Comparison**

### *Program Design and Development*

In program IV, we utilize Android phones' wireless connectivity to the Internet to transfer data from smartphones to a remote system sever, thereby allowing for inter-participant comparison. Individual weekly data are scheduled to be sent to a remote server from all participants' android phones at 11:45pm on Sunday evenings. The application running on the server processes the data, develops weekly inter-participant comparison reports, and sends the comparison reports to participants at 10:30am on the following Monday. The weekly report summarizes the participant's total physical activity and travel-related physical activity conducted in the past week, and compares the participant's physical activity amount with the recommended physical activity amount provided by the Center for Disease Control and Prevention. More importantly, the weekly report offers comparison results among peers. It compares each participant's physical activity level with that of the rest of sample, informing the participants how well they did compared to their peers. Also, it compares this week's physical activity levels with their records from the previous week(s), providing information on whether there is any progress achieved. Figure 6 and Figure 7 show an example of the smartphone-based weekly report.

### *Pilot Testing*

A three-week pilot testing was carried out to test this weekly report system. The test was successful and the weekly reports were properly displayed on smartphone at pre-schedule times—Monday morning at 10:30am following each week. Sample snapshot of the weekly report are illustrated in Figures 3.5 and 3.6 below.



FIGURE 3.5 Weekly Report Part 1: Physical Activity and Experience Summary

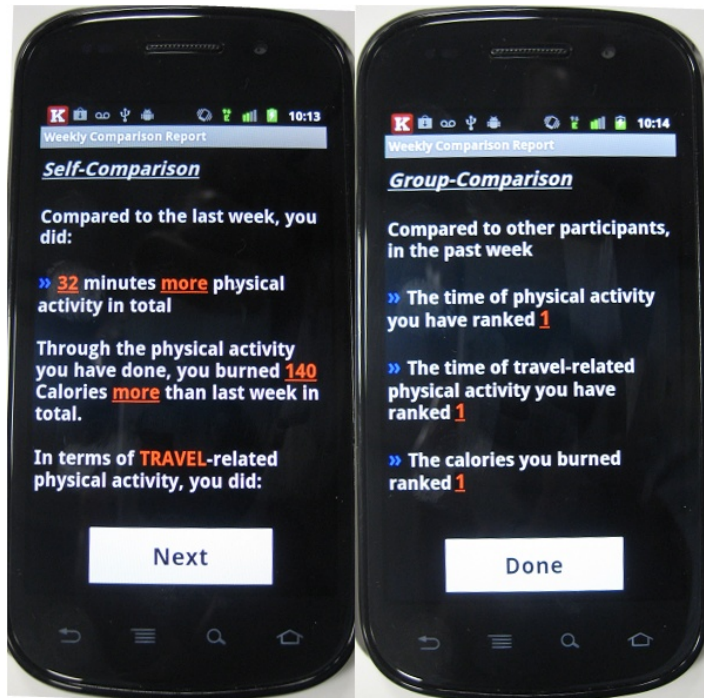


FIGURE 3.6 Weekly Report Part 2: Intra- and Inter-Participant Comparisons

## **Impacts of UbiActive on Phone Performance**

We also deployed and tested the impact of UbiActive on smartphones' network usage, memory requirement and battery life using a Samsung Nexus S Google phone. Testing results shows a minimal impact of UbiActive on network usage. The smartphone sends data back to server each day for weekly report, and the data size is less than 1 KB per day. As for memory requirement, UbiActive collects about 7Mb of raw sensor data and statistics per day. Therefore, for 3-week study period, the application needs at least 150Mb storage space. With UbiActive running in the background continuously, the battery life of our testing phone (Nexus S) is about 12-15 hours without additional voice/text/data usage.

## CHAPTER 4: THREE-WEEK FIELD STUDY

A three-week field study is designed to test the viability of UbiActive for data collection and behavior intervention. The field study includes three phases of work: (1) study design; (2) study implementation; (3) data analysis.

### Study Design

The objective of the three-week field study is to test the UbiActive prototype for its feasibility and reliability in tracking and intervening participants' travel behavior. We are also interested in the variability of the UbiActive's performance on various smartphones, and UbiActive's potential in promoting healthier travel behavior

Participants, randomly assigned to intervention and control groups, were asked to wear their smartphone with UbiActive installed on the right hip during all waking hours except water activities for three consecutive weeks. For the intervention group, the first week of participation is pre-intervention data collection and the third week is post-intervention data collection, i.e., in these two weeks the application merely collects data on participants' travel-related physical activity and well-being status. In the second week, besides collecting information, the application was designed to generate daily reports about the participant's travel-related physical activity and well-being information. The generated daily reports were displayed on participants' smartphone summarizing the following information: (1) total duration of physical activity in the past day; (2) total duration of physical activity related to travel; (3) calories burned by travel and non-travel physical activity; (4) the proportion of trips with positive travel experience. The application was also design to display summaries of participants' travel-related physical activity and well-being information on a weekly basis during all the three weeks of participation to increase participants' awareness about the potential cumulative impact of travel behavior on physical and mental health. The weekly summaries include (1) the participant's total physical activity and travel-related physical activity conducted in the past week; (2) comparison with the recommended physical activity amount provided by the Center for Disease Control and Prevention; (3) comparison with the rest of the intervention group; (4) comparison with records from the previous week(s) to see whether there is any progress achieved. For the control group, the application was only designed to collect data for three weeks. None of the collected information was shared with the participation during the three weeks (as shown in Table 4.1).

The hypothesis that active information sharing would contribute to promoting healthier travel behavior is drawing on two behavioral theories: the health belief model (Rosenstock 2005; Glanz, Rimer et al. 2008) and the I-change model (De Vries, Dijkstra et al. 1988; De Vries and Mudde 1998).

As a health behavior change model, the health belief model states that four factors would affect people's likelihood of health-related behavior change: perceived susceptibility, perceived severity, perceived barriers and perceived benefits. Perceived susceptibility refers to estimated

probability of a targeted event such as an occurrence of a certain kind of disease or unhealthy status. Perceived severity refers to estimated seriousness of the targeted event. Perceived barriers emphasize the perceived factors that hinder promoted behavior change. And perceived benefits specifically refer to perceived positive outcomes after adopting the promoted behavior. In our study, the targeted event is physical activity level and its related health outcome. Our intervention provides information on the total daily amount of physical activity and how far it is from the CDC suggested standards, which helps participants to understand their physical activity level and the possible gap between the actual level and suggested health-benefiting standard, and thereby influences participants' perceived susceptibility and severity. In addition, we expect to change people's behavior by influencing perceived benefits. Most participants may not be aware of the physical activity benefits associated with travel. Having information on the specific travel-related physical activity amount, UbActive provides message reminders such as "If you switch from passive travel modes to active ones, you could burn even more calories daily". We expect these reminders to help participants realize the potential benefits of taking active trips. Likewise, as participants may not reflect on their travel well-beings status associated with current travel modes, UbiActive provides travel experience summary to help participants to reflect more on their current experience and potential room for improvement.

The I-change model distinguishes the process of behavior change into three phases: awareness, motivation and action. That is, a clear understanding of the individual's particular behavior (in our case, the amount of physical activity conducted and how far it is from the CDC suggested standards) is the basis of possible behavior change. Then, personal attitude, social influence beliefs (influence from external environments), and self-efficacy expectations (the perceived personal ability to adopt a promoted behavior) are considered as motivation for behavior change. The last phase is the action of behavior change which is determined by action planning, goal setting, and so forth. Consistent with the health belief model, the I-change model also emphasizes the important role of accurate knowledge and perceived risk/benefits of the individual's behavior in promoting behavior change. In this research, we hypothesize that active information sharing addresses the "awareness" and "motivation" phase, helps to equip participants with accurate knowledge of their current physical activity level, consider more active travel behavior as an effective way to augment physical activity and the associated health benefits, and induces active travel behavior.

**TABLE 4.1 Frequency of Information Sharing for the Intervention and Control Groups**

	<b>1<sup>st</sup> Week</b>	<b>2<sup>nd</sup> Week</b>	<b>3<sup>rd</sup> Week</b>
	Baseline	Intervention	Post- Intervention
<b>Intervention Group</b>	Weekly	Daily and Weekly	Weekly
<b>Control Group</b>	None	None	None

After three weeks of data collection, participants were invited back for researchers to collect the data stored in their smartphones’ memory cards. In addition, participants were invited to take a web-based Exit Survey (See Appendix H) about their general experience with the field study, perceived strength and weakness of UbiActive and study design, perceived difficulties in complying with the participation requirements, and concerns about privacy issues.

### **Study Implementation**

Recruitment of study participants started in October 2011. The convenience/snowballing sampling technique was used. The goal was to recruit 30 young adults who owned an android phone and aged between 18 and 35 from the University of Minnesota campus to participate in our study. The recruitment method includes posting printed flyers (see Figure 4.1) around campus and sending emails to departmental listservs. By November 2011, a total of 23 young adults owning an android phone with a basic data plan and with an Android OS version 2.2 or 2.3 were successfully enrolled in our study. At the beginning of the recruitment, we planned to recruit people with Android version later than 2.3. Later, we developed a modified version of the application that can be used on phones with Android version 2.2.



# Research Participant Recruitment

## ARE YOU THE ONE?

- ✓ Aged between 18-35
- ✓ Owning an Android smartphone with Android version earlier than 2.0 or later than 2.3 with basic data plan
- ✓ NOT having any health problem, condition or disability preventing you from conducting active travel behavior
- ✓ Have NOT worked for any institute for survey research
- ✓ Have NOT participated in any research about physical activity or travel behavior in the past six months

You are invited to participate in a research investigating travel experience, which will be conducted by researchers from Hubert H. Humphrey School of public affairs and the Minnesota Traffic Observatory, University of Minnesota in October. Upon completion of the study, participant would receive a compensation **UP to \$100!**

All you need to do is carrying your smartphone which would be installed our apps during all waking hours for three consecutive weeks, completing surveys sent to your smartphone after each trip you conducted and filling daily travel diaries. If you are interested, please send an email to [smtphone@umn.edu](mailto:smtphone@umn.edu) before **Sept. 18th**. More information can be found: <http://z.umn.edu/smartphone>

**ANDROID USER WANTED**

**FIGURE 4.1 Participant Recruitment Flyer**

To ensure quality of testing, we did not recruit people with any health problem, condition or disability preventing them from conducting active travel behavior. We also excluded people working for survey research institutes or have participated in any research about physical activity or travel behavior in the past six months.

People interested in this study were first asked to complete a web-based General Background Information Survey (See Appendix D) which contained screening questions. The web survey also contained questions about participants’ demographic attributes, self-reported health status, habitual travel behavior, and factors that affect their mode choice. Note that this research is exploratory in nature. Given the small sample size, findings from this research cannot be generalized to any population groups. Information gathered from the web survey is included in the final dataset and part of the information is used to explain participants’ behavior and ratings collected from the field study.

Eligible participants were invited to an orientation meeting and provided with an information sheet (see Appendix E, a scanned copy of the information Sheet for participants in the intervention group) which described the general scope of this study, their responsibilities as a participant, confidentiality and voluntary nature of this research, as well as the amount of compensation they would receive. People who agreed to participate were then provided with detailed information on the functions of the UbiActive application and precautions needed for a successful participation experience. In addition, participants were provided with a DOs-and-

DON'Ts sheet (see Appendix F, a scanned copy of the sheet for the intervention group) to further clarify and emphasize the procedures they should perform in the three study weeks for maximum compensation. A paper-version travel diary booklet (see Appendix G) was also provided to participants to record their daily trip information with a pen-and-paper instrument.

Each participant was informed that they would receive up to \$100 as compensation for their three-week participation, and the amount of compensation would be dependent on the number of days they carried smartphone appropriately:

- **\$100:** if the participant wears phone properly (meaning carry smartphone on the right hip using the phone case provided by the researchers), completes at least 70% of the phone-triggered surveys, and fills out the paper-version travel diary for at least **FOUR DAYS A WEEK** (including at least one weekend day) during the three weeks of participation.
- **\$ 75:** if the participant wears phone properly, completes at least 70% of the phone-triggered surveys, and fills out the paper-version travel diary for at least **THREE DAYS A WEEK** (including at least one weekend day) during the three weeks of participation.
- **\$ 50:** if the participant wears phone properly, completes at least 70% of the phone-triggered surveys, and fills out the paper-version travel diary for at least **TWO DAYS A WEEK** (including at least one weekend day) during the three weeks of participation.

Over the three weeks of study, 6 participants dropped out due to various reasons, such as unwillingness to continue or phone lost, resulting in a final study sample of 17 participants. Of the 17 participants, 10 participants received intervention. As for the demographic characteristics, 5 participants were females; 7 participants (41%) were full-time undergraduate students, 8 were full-time graduate or professional students (48%), 1 was a part-time undergraduate student (6%), and 1 was an alumni (6%). The average age of participants was 23. The participants used different types of Android phones, including Samsung, HTC, LG and Motorola. Table 4.2 shows the descriptive statistics of study sample.

Vehicle access was not universal in the study sample: Only 41% of the participants owned a private vehicle. When asked “last week, for work-related/school-related commute trips, which mode did you use most frequently?”, 8 (47%) participants reported walking as their most frequently used mode, 5 (29%) participants reported bus and 3 (18%) reported bicycle. When asked “last week, for non-work/non-school trips, which mode did you use most frequently?”, 9 (53%) participants reported car, and 5 (29%) participants reported walking, 2 (12%) participants reported bus, and 1(6%) reported bicycle.

**TABLE 4.2 Characteristics of the Study Sample (N=17)**

<b>Variable</b>	<b>N (%)</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>
<i>Intervention Applied</i>	<u>10 (59%)</u>				
<i>Socio-demographic characteristics</i>					
Gender					
Female	5 (29%)				
Male	12 (71%)				
Race					
White Only	9 (53%)				
Black or African-American	1 (6%)				
Asian Only	5 (29%)				
Multi-racial	1 (6%)				
Other	1 (6%)				
Age		23.35	2.95	19	30
Occupation					
Full-time undergraduate student	7 (41%)				
Full-time graduate or professional student	8 (49%)				
Part-time undergraduate student	1 (6%)				
Alumni	1 (6%)				
<i>Smartphone Brand</i>					
HTC	4 (24%)				
LG	1 (6%)				
Motorola	6 (35%)				
Samsung	6 (35%)				
<i>Travel Behavior</i>					
Vehicle Ownership (the number of vehicle owned/ household size)	7(41%)				
Major mode for work/school-related commute last week					
Walking	8 (47%)				
Bicycle	3 (18%)				
Car	1 (6%)				
Bus	5 (29%)				
Major mode for non-work commute last week					
Walking	5 (29%)				
Bicycle	1 (6%)				
Car	9 (53%)				
Bus	2 (12%)				

## **Analysis of Phone-Based Sensor and After-Trip Survey Data**

In this section, we analyze data collected from UbiActive, including sensor-collected speed, location, and acceleration data as well as program-triggered after-trip survey data.

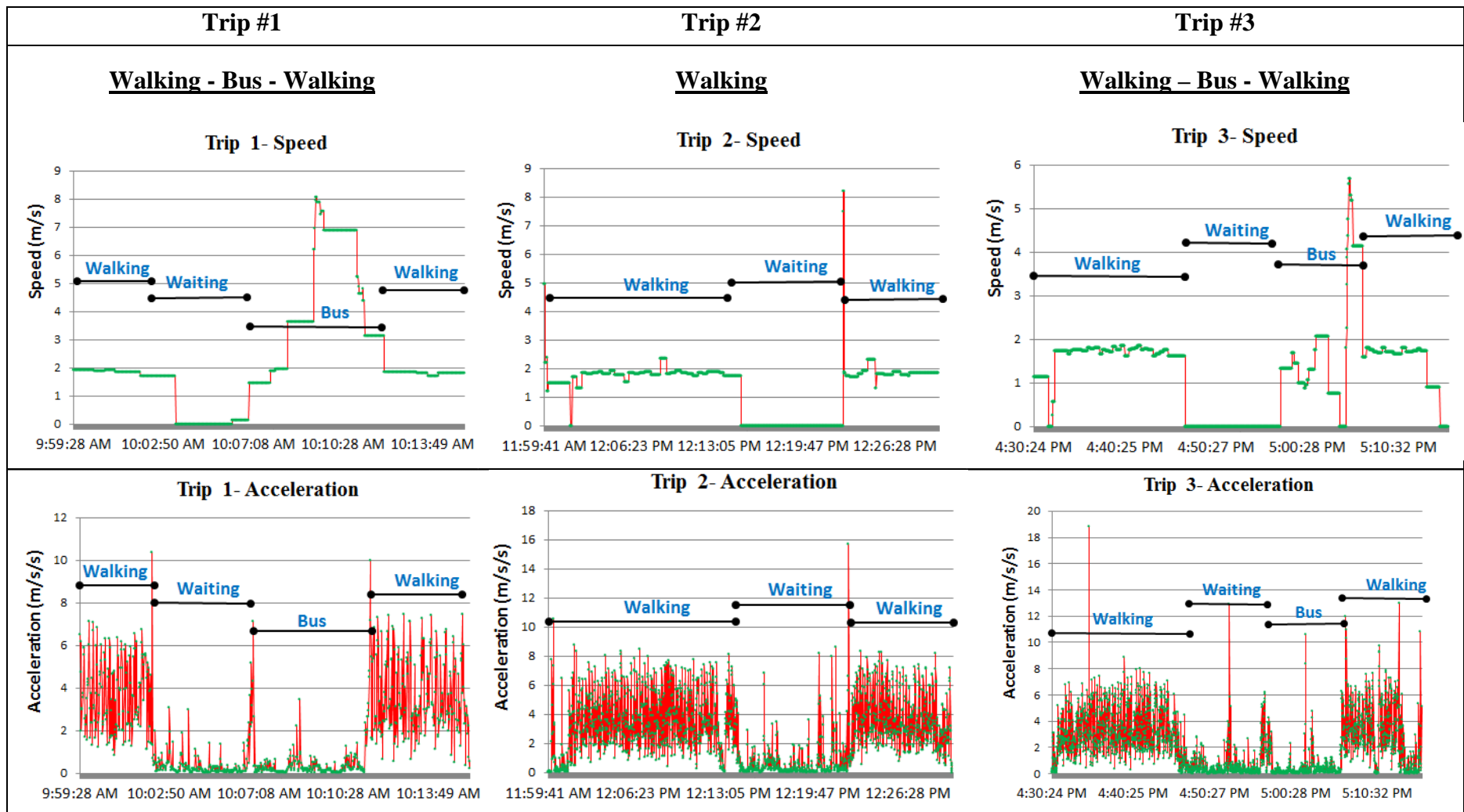
### *A Case Study*

The data shows that a deep understanding of participants' travel behavior could be obtained through smartphone-based sensor data and after-trip survey data, including trip frequency, mode, trip start/end time, purpose, companionship, secondary activity and psychological experience. Tables 4.3 and 4.4 show the captured trip information of one participant on November 13, 2011. The participant conducted a total of 3 trips on that day, including of a school commute trip (10:00am-10:15am), a meal trip (12:00-12:30pm) and a back-to-home trip (4:30-5:15pm). With longitude and latitude information sampled every 30 seconds, this participant's trip routes were easily delineated as shown in Table 4.3. Speed and acceleration profiles in combination with after-trip survey responses showed that one of the three trips was walking only, and the other two were multi-mode trips (See Table 4.4). Travel experience of this participant was generally positive on the example day as shown in Table 4.3.

**TABLE 4.3 Trip Information of a Participant on November 3, 2011 – Part I**

	Trip #1	Trip #2	Trip #3
	<p>© 2012 Google Map Data</p>	<p>© 2012 Google Map Data</p>	<p>© 2012 Google Map Data</p>
<b>Start Time</b>	10:00am	12:00pm	4:30pm
<b>End Time</b>	10:15am	12:30pm	5:15pm
<b>Trip Purpose</b>	School	Meal	Back Home
<b>Mode</b>	Walking – Bus - Walking	Walking	Walking – Bus - Walking
<b>Companionship</b>	Alone	Alone	Friends/Schoolmates/ Neighbors/Acquaintances
<b>Secondary Activity</b>	Doing Nothing	Doing Nothing	Talking/Conversation/Making Phone Call
<b>Satisfaction of Trip</b>	★★★★☆	★★★★☆	★★★★☆
<b>Does this trip make you feel good?</b>	★★★★☆	★★★★☆	★★★★☆
<b>Do positive aspects outweigh the negative of the trip?</b>	★★★★☆	★★★★☆	★★★★☆
<b>In general, how happy were you during this trip?</b>	★★★★☆	★★★★☆	★★★★☆

TABLE 4.4 Trip Information of a Participant on November 3, 2011 – Part II (Sampling Frequency is 1Hz)



### *Trip Summary of the Study Sample*

- Daily Trip Frequency and Mode Choices

The phone-based survey data shows that a total of 509 trips with trip duration longer than 10 minutes and with complete after-trip survey information reported by the 17 participants during the 3-week period. These valid trips occurred in 256 days, resulted in an average trip frequency of two trips per person per day. Characteristics of these 509 trips are summarized in Table 4.5. Of these trips, 36% of the trips were made on foot, 1% by bike, 26% by private car, and 37% by transit. The low bicycling rate might be due to the fact that the study was conducted between Oct 28 and November 23, and the early winter weather might have limited bike use.

**TABLE 4.5 Characteristics of the Recorded Trips (N=509)**

<b>Variable</b>	<b>N (%)</b>	<b>Mean</b>	<b>Std. Dev.</b>
Duration (min)		43	28
Mode			
Walking	184 (36%)		
Bicycle	5 (1%)		
Car	129 (25%)		
Bus	187 (37%)		
Train	4 (1%)		
Purpose			
Return home	146 (29%)		
School-related	151 (30%)		
Meals- or eating-related	54 (11%)		
Work-related	49 (10%)		
Shopping/errands	44 (9%)		
Socializing/hang out	17 (3%)		
Family or Personal business/Obligations	13 (3%)		
Recreation/fitness activity	11 (2%)		
Transport someone	6 (1%)		
Civic/religious activities	7 (1%)		
Other reasons	11 (2%)		
Companionship			
Alone	285 (56%)		
Friends/schoolmates/neighbors/acquaintances	171 (34%)		
Spouse/unmarried partner	30 (6%)		
Other Family Member	9 (2%)		
Multiple companion	11 (2%)		

- Trip Purpose and Companionship

The major purposes of the trips were returning home, school and work commute, meals and shopping. Specifically, 29% of trips were back-to-home trips, 30% were school-related, 10% were work-related, 11% were meals or eating-related and 9% were shopping/errands. The majority of the trips (56%) were made alone, 34% were accompanied by friends/schoolmates/neighbors/acquaintances, and the rest of the trips were accompanied by spouse/unmarried partner or other family member.

- Trip Experience

Table 4.6 summarizes participants’ responses to the four travel experience/well-being questions in after-trip surveys. The majority of the 509 trips were reported with positive travel experience: 65% of the trips were reported satisfied; 61% of the trips were considered making the participants feel good; 70% of the trips were reported with positive aspects outweighing the negative ones; and participants reported being happy during 67% of the trips.

**TABLE 4.6 Travel Experience/Well-Being Summary (N= 509 trips)**

<b>How satisfied were you with this trip?</b>	<b>1 -Completely unsatisfied</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5 – Completely satisfied</b>
	0.39%	4.63%	29.73%	36.10%	29.15%
<b>How good did this trip make you feel?</b>	<b>1 – Not good at all</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5 – Very good</b>
	0.58%	5.21%	33.59%	31.47%	29.15%
<b>When you think of this trip, do positive aspects outweigh the negative?</b>	<b>1 - Negative aspects outweigh the positive</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5 – Positive aspects outweigh the negative</b>
	0.77%	2.90%	25.87%	31.08%	39.38%
<b>In general, how happy were you during this trip?</b>	<b>1 – Not happy at all</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5 – Very happy</b>
	0.19%	3.09%	30.12%	35.91%	30.69%

*Potential for Behavior Intervention*

To evaluate the potential of UbiActive for behavior intervention, we tested if percent of walking and biking trips differed significantly between the first and the third study week among the intervention and control groups. Three participants who did not produce valid data in the third study week were excluded from this analysis. Because the observations do not follow normal distribution, the Mann–Whitney U test (also called the Mann–Whitney–Wilcoxon test) (Mann and Whitney 1947) is used. The null hypothesis is that the daily percentage of walking and biking trips in the first week is equal to the percentage in the third week. The alternative hypothesis is the daily percentage in the first week is smaller than the third week. Based upon the



test results shown in Table 4.7, the daily percentage of walking and biking trips is numerically larger in the 3<sup>rd</sup> week than the 1<sup>st</sup> week for both of the intervention and control groups. The differences were not statistically significant. That is, we did not observe any significant evidence of behavior change. Two factors may explain the insignificance:

- The sample size is too small to draw solid conclusions at a reasonable significance level. The number of observations of treatment group in the first and the third week are only 34 person-days and 40 person-days respectively, and the number of observations of control group in the first week and the third week is 31 person-days and 33 person-days.
- The field study was implemented in November in Minnesota where the cold weather might discourage possible mode shifts to from automobiles to walking and biking.
- The intervention only lasted for one week, which may not be long enough to accumulate significant influential power to promote participants’ travel behavior change. Having that said, it is difficult to implement a longer intervention period because a longer field study is likely to result in a much lower participant compliance level.

**TABLE 4.7 The Mann–Whitney U Test of Walking and Biking Usage Difference between the 1st and 3rd Week**

	Percentage of walking and biking trips (%)			W-Statistic	P-Value
	1 <sup>st</sup> week	3 <sup>rd</sup> week	Difference		
<b>Intervention Group</b>	48.39%	51.06%	2.67%	587.0	0.8668
<b>Control Group</b>	31.67%	40.93%	9.26%	501.5	0.5603

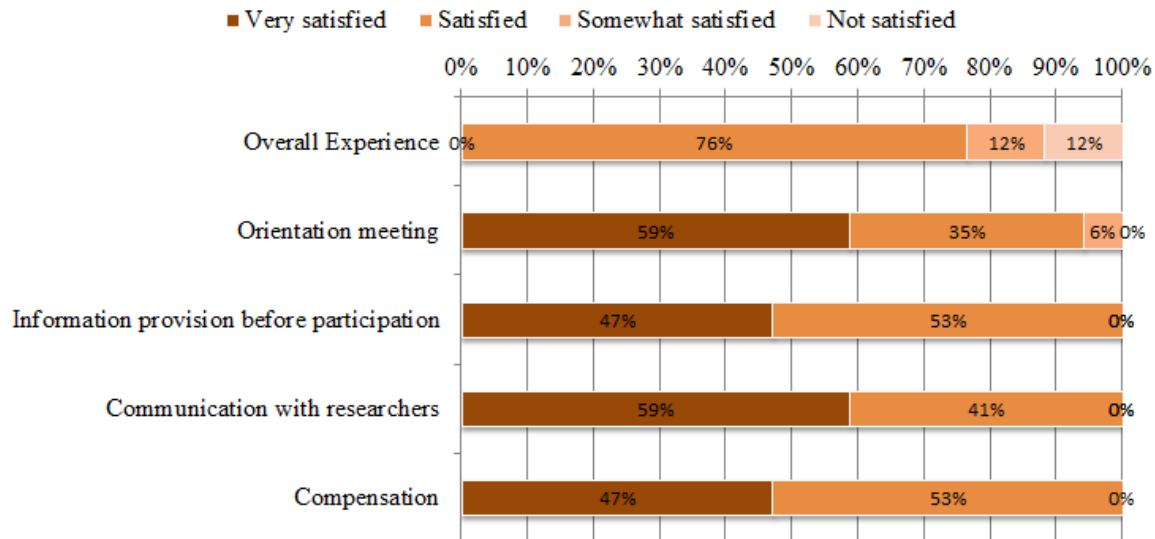
Nonetheless, results from the web-based Exit Survey indicate that participants became more aware of their travel behavior, travel-related physical activity, and travel experience/well-being after participating in the field study (see Figure 4.4 in the following section).

### **Analysis of Web-Based Exit Survey Data**

The Exit Survey collects participants’ feedbacks regarding study design, application performance, participation requirements, and privacy and other concerns. Data from the Exit Survey are intended to identify strengths and weaknesses of this study.

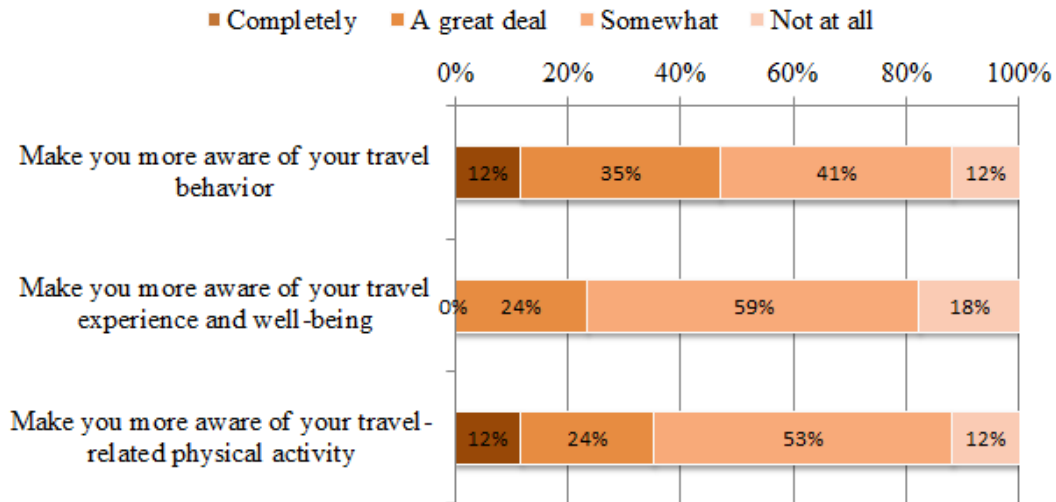
### Participation Experience

Participants have high satisfaction with the three-week field study. Out of the 17 participants, 13 (76%) participants reported having a “satisfied” overall experience, 2(12%) participants felt their overall experience was “somewhat satisfied” while 2(12%) participants reported they were not satisfied with the overall experience. Participants gave relatively high ratings to the organization of the field study (e.g., orientation meeting and information provided) and the compensation provided. See Figure 4.2.



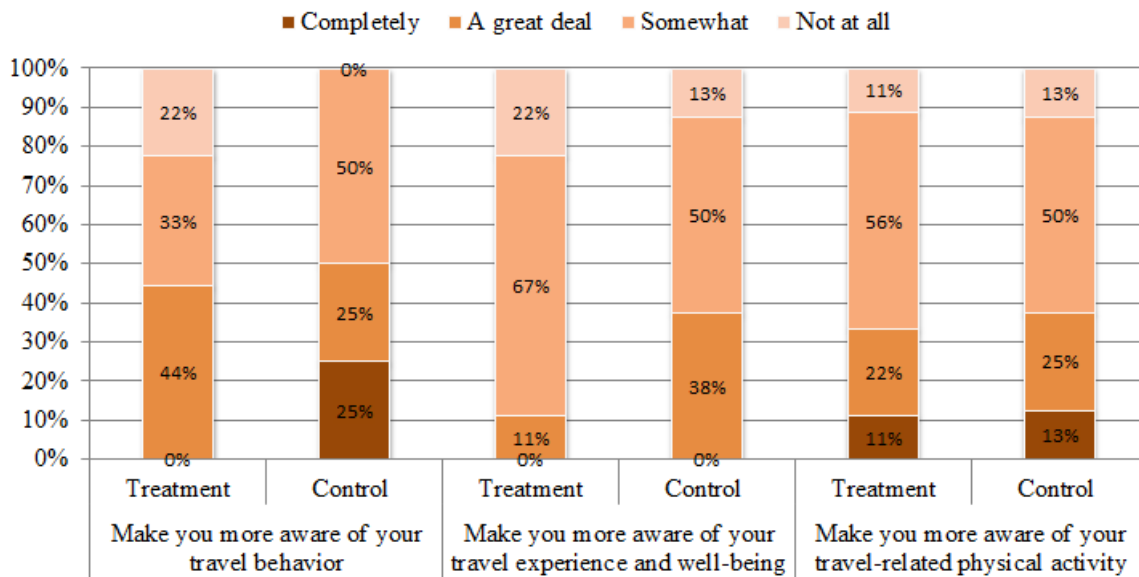
**FIGURE 4.2 Participant Satisfaction with the Study Experience (N=17)**

When asked “did your participation in this study make you more aware of your travel behavior?”, out of 17 participants, 2 (12%) participants selected “completely”, 6 (24%) participants selected “a great deal” and 7 (53%) participants selected “somewhat”. When asked “did your participation in this study make you more aware of your travel experience and well-being?”, 4 (24%) participants reported “a great deal” and 10 (59%) participants reported “somewhat”. When the treatment group was asked “did your participation in this study make you more aware of your travel-related physical activity?”, 2 (12%) participants reported “completely”, 4 (24%) reported “a great deal” and 9 (53%) reported “somewhat”. See Figure 4.3.



**FIGURE 4.3 The Effects of Participation on Awareness of Travel-Related Health Impacts**

Interestingly and unexpectedly, when comparing between intervention and control groups, participants in the control groups reported higher levels of awareness about travel-related health impacts, as shown in Figure 4.4. Although the difference is insignificant, the comparison somewhat illustrates that merely participating in a study about health impacts of travel behavior (just knowing to have a tracking device recording physical activity and doing survey on psychological experiences of travel) could have an awareness impact.



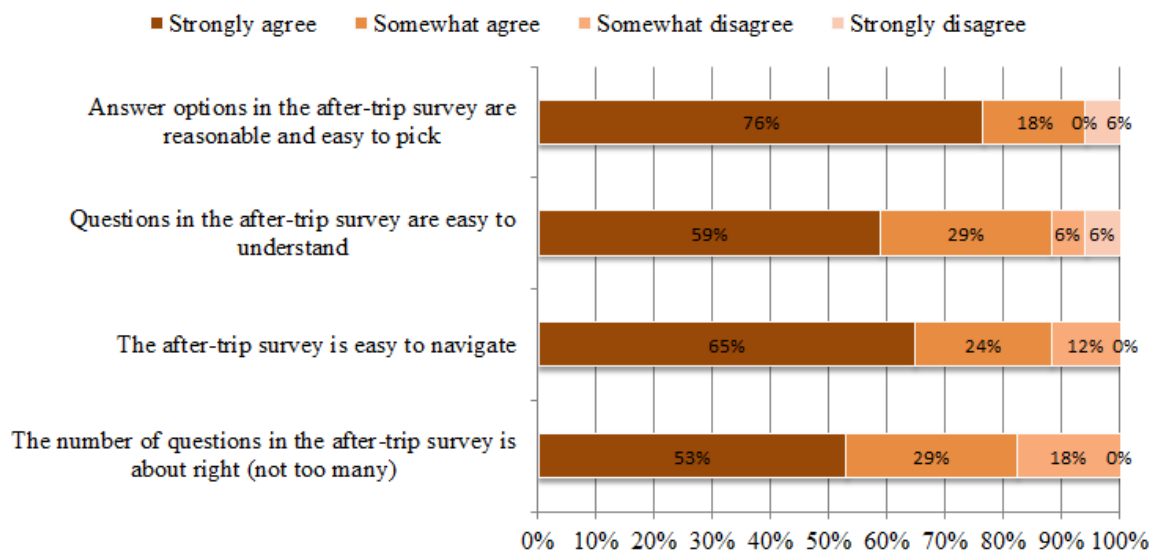
**FIGURE 4.4 The Effects of Participation on Awareness of Travel-Related Health Impacts between the Intervention and Control Groups**

## Study Design & UbiActive's Performance

- Smartphone-Based After-Trip Survey

Survey results indicate participants are more willing to take phone-based survey instead of using a pen-and-paper instrument to report their travel information, due to the instantly documenting ability and high portability of smartphone. When asked whether they would agree with the statement "I would have preferred to enter travel behavior information on pencil and paper, instead of having smartphone automatically detecting such information", the major of participants (59%) selected "strongly disagree" and 29% selected "somewhat disagree", only 2 (12%) participants selected "somewhat agree" or "strongly agree". And some participant explained the reason: "I often didn't carry my travel diary with me so I had to record times in my phone".

In terms of the design and layout of the phone-based survey, participants reported a high level of satisfaction with question wording, design of answer options, ease of navigation and survey length (See Figure 4.5). Thirteen (76%) participants strongly agreed with the statement that "answer options in the after-trip survey are reasonable and easy to pick". Ten (59%) participants strongly agreed with the statement that "questions in the after-trip survey are easy to understand" while 5(29%) participants selected "somewhat agree". Eleven (65%) participants strongly agreed that "the after-trip survey is easy to navigate" and 9 (53%) participants strongly agreed that "the number of questions in the after-trip survey is about right (not too many)".



**FIGURE 4.5 Feedback on Smartphone-Based After-Trip Survey**

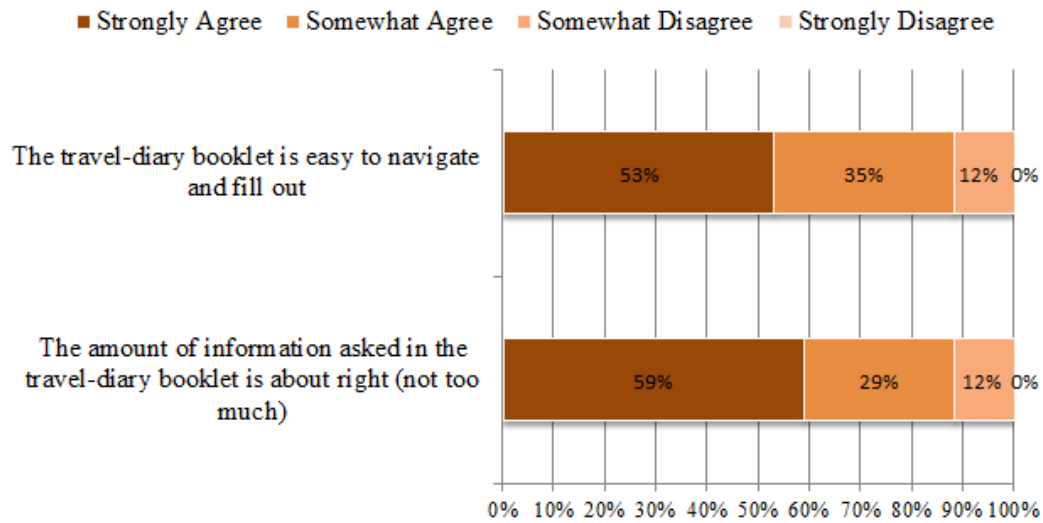
Participants suggested room for improvement when it comes to UbiActive's ability of trip detection. When asked "how satisfied are you with UbiActive's ability of trip detection?", 1 (6%) participant reported "very satisfied", while "satisfied" and "somewhat satisfied" each has 5 (29%) participants selected, 6 (36%) participants selected "unsatisfied". It is worth noting that

UbiActive's ability of trip detection varied significantly by the type of phones and destinations. For example, when asked "out of all the longer-than-10-minute trips you made during the three weeks of participation, for what percentage of these trips you were able to receive automatically triggered after-trip surveys?", the reported auto-triggering rate of phone-based survey ranges from 0%-90%. The median of the reported auto-triggering rate is 50% with the 1<sup>st</sup> quartile of 35% and the 3<sup>rd</sup> quartile of 65%. The low auto-triggering rates were mainly reported by Motorola Droid and HTC Merge users.

The variability in trip detection accuracy among different phones is not surprising because UbiActive's ability of trip detection is highly dependent upon instant location updating of GPS sensor, which is determined partly by the accuracy of the GPS sensor in the phone and partly by the GPS signal strength at destination. It is likely that GPS sensor of Motorola Droid series have relative lower accuracy, leading to generally lower triggering rates. In addition, participants confirmed the triggering rate of phone-based survey varies significantly by the environment of destination. When asked "did you feel that the accuracy of trip detection varies by the kind of trips you made?" 59% participants answered "Yes", and some of them specified the differences: "when destinations are close rooms, it never triggers"; "Trips ending in buildings seemed to be less likely to trigger a trip detection"; "The apps was very limited in triggering when traveling to buildings".

- Paper-Version Travel Diary Booklet

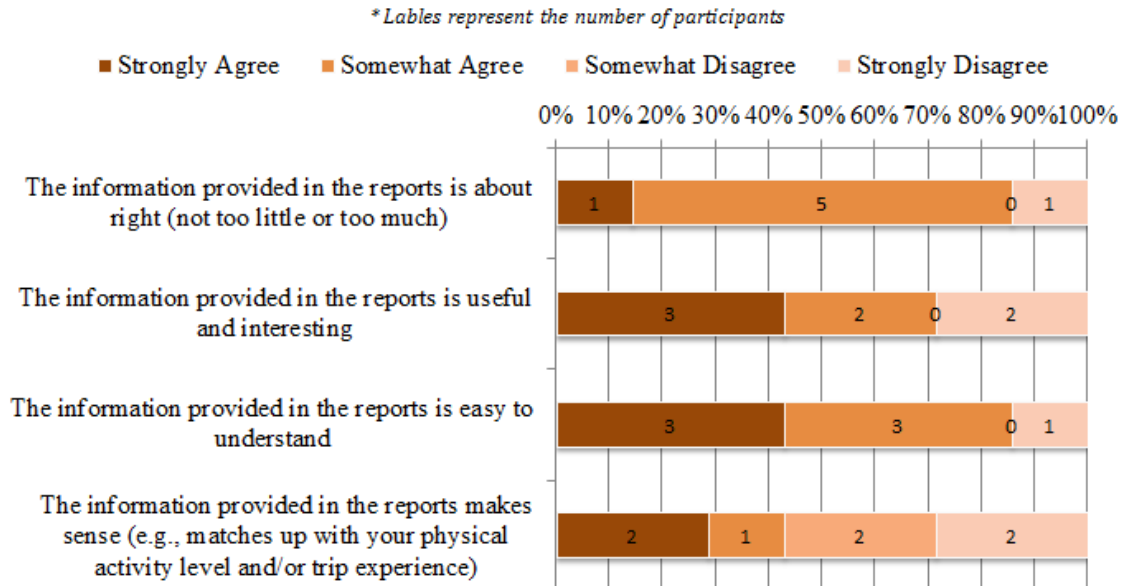
Participants in general agreed that the paper-version travel diary booklet is well-designed, easy to navigate, and asks right amount of information (See Figure 4.6). Specific comments on the booklet include: "it was straightforward and easy to fill out"; "I appreciated that there was a separate page for each day which reminded me to complete the written survey daily (and prevented me from accidentally skipping a day)". Interestingly, although participants considered the booklet to be well-designed, they still had difficulties in filling it out every day. Some participants complained "it was easy to forget filling out", "physical travel log for a digital traveling application is an unnecessary burden, and I would be willing to bet that most of the data on those sheets was very rough and/or inaccurate."



**FIGURE 4.6 Feedback on Paper-Version Travel Diary Booklet**

- Daily & Weekly Reports on Travel-Related Physical Activity and Well-Being

In the Exit Survey, participants in the intervention group were asked additional questions about their opinions on daily and weekly reports. Seven participants answered this set of questions. They in general spoke highly of the information shared via daily and weekly reports (as shown in Figure 4.7): out of 7 participants, 6 participants strongly/ somewhat agreed that the information provided in the reports is about right and easy to understand; 5 participants strongly/somewhat agreed that the information provided in the reports is useful and interesting, and makes sense at the same time. However when asked to provide suggestions to further improve the daily and weekly reports, participants mentioned that the accuracy of energy-consumption statistics in daily and weekly reports needed significant improvement.



**FIGURE 4.7 Feedback on Daily and Weekly Reports**

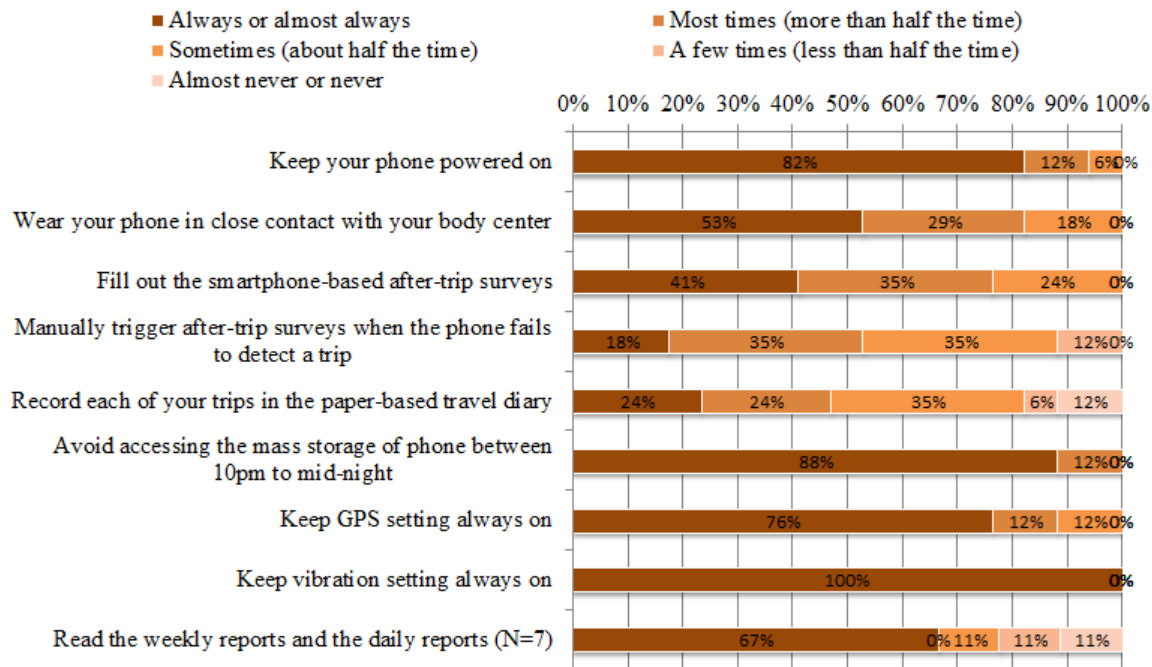
- Battery Life

Participants’ feedbacks showed that the amount of battery consumed by UbiActive varied significantly by phone. Through asking participants the battery life before and after installation of the UbiActive, we found that UbiActive shortened various smartphones’ original battery life for a range from 25% to 83%. The median percentage is 56% with the 1<sup>st</sup> quartile of 38% and the 3<sup>rd</sup> quartile of 68%. The newer released smartphone appeared to have longer battery life and be less influenced by UbiActive’s battery consumption.

*Compliance with Participation Requirements*

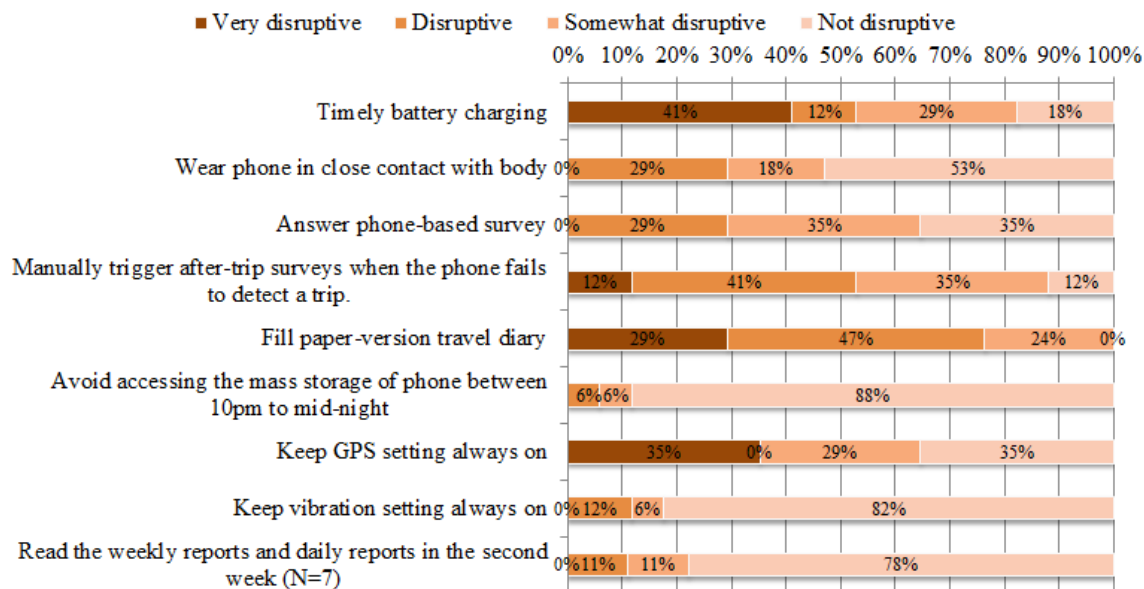
To ensure proper functioning of UbiActive, we provided participants with a sheet of DOs and DON’Ts that listed actions they are recommended to perform and actions they should avoid (see Appendix F). Although the list helped to achieve quality study results, it was concerned whether the requirements on the list are user friendly. In the Exit Survey, participants were asked how they performed in compliance with the participation protocol and how disruptive the requirements were. Survey results (See Figure 4.8) show that participants performed well in compliance with most required actions, except the requirement to fill out the paper-version travel diary and to manually trigger after-trip surveys when the phone failed to detect a trip. Specific comments from the participants show that the low compliance rate of paper-version travel diary attributes to the low portability of a pen-and-paper instrument. Some participant reported “not having trip diary on me and forgetting to write down trips later” and “at the end of the day I would sometimes forget about a trip that I had taken earlier in the day and forget to write that trip down.” The most common reasons preventing participants from manually triggering after-trip

survey were forgetting or daily activities like taking classes that make self-triggering inconvenient.



**FIGURE 4.8 Compliance with Participation Requirements**

Participants were also asked how disruptive the participation requirements were to their everyday life. As shown in Figure 4.9, participants suggests the most disruptive requirements to be timely battery charging, filling paper-version travel diary and keeping GPS setting always on.

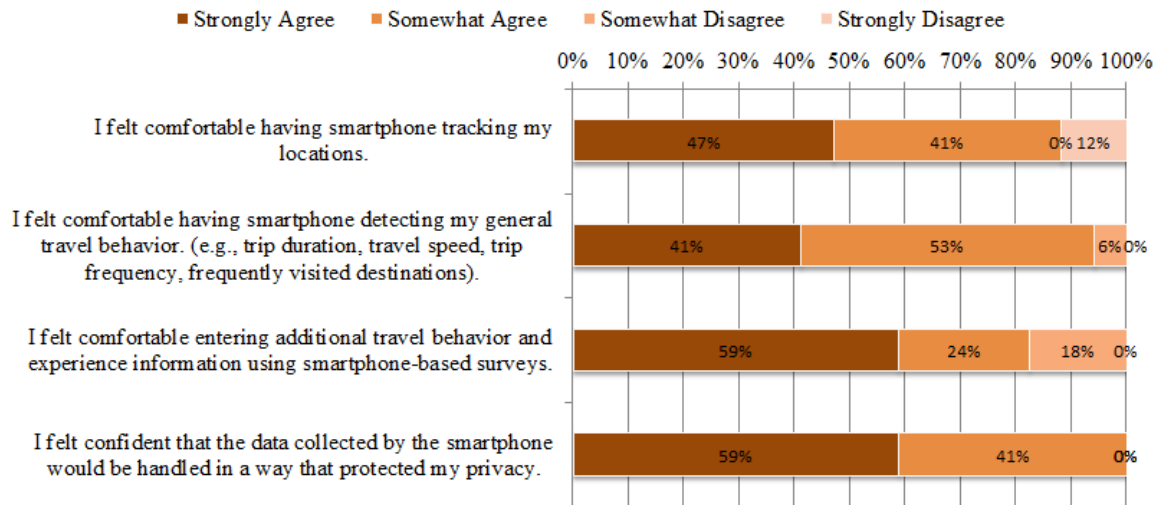


**FIGURE 4.9 Disruptiveness of Participation Requirements**



*Privacy Issues*

Before the field study, participants were well-informed the types of information to be collected, and confirmed that all collected information would be securely kept. A question in the Exit Survey asked participants to describe “understanding of what data were collected on your phone, who will have access to the data, and how the data will be handled”. Participants’ answers confirmed that participants were well-communicated about these privacy concerns. For example, the following is one participant’s answer to the above question: “I understood that the data being collected on my phone was GPS and accelerometer based information, including location, speed, acceleration, as well as behavior and experience information that I entered manually. The research group will be accessing the data, and it will be used for the purposes of statistical analysis related to the research project. Once it is no longer needed, it will be deleted.” Through quality communication ahead of the field study, participants felt comfortable about the data collection and experience sampling over the study period. Fifteen (88%) participants “strongly agree” or “somewhat agree” that they felt comfortable having smartphone tracking their locations. Sixteen (98%) participants at least “somewhat agree” that they felt comfortable having smartphone detecting their general travel behavior. Fourteen (83%) participants agreed that they felt comfortable entering additional travel behavior and experience information using smartphone-based surveys. All participants agreed that they felt confident the data collected by the smartphone would be handled in a way that protected their privacy. See Figure 4.10.



**FIGURE 4.10** Participants' Opinions on Privacy Issues Associated with the Study

## CHAPTER 5: CONCLUSIONS AND FUTURE DIRECTIONS

In this report, we have presented UbiActive, a robust, smartphone-based application for monitoring respondents' transportation routines, examining travel-related health and well-being impacts, and intervening for healthier and happier travel behavior. Utilizing smartphone's built-in sensors, UbiActive is able to collect real-time information on user's location, movement time, speed, acceleration, and orientation, all of which help to derive travel distance, duration, and mode of each trip as well as to measure physical activity intensity, duration, and the associated energy expenditures. In addition, through detecting trips and triggering survey actions on the smartphone immediately after a trip is detected, UbiActive collects in situ self-reported psychological experience during the trip.

A three-week field study was designed to test the viability of UbiActive for data collection and behavior intervention. Analysis of the data collected in the field study shows UbiActive could provide a deep understanding of participants' travel behavior. As for behavior intervention, we tested if percentage of walking and biking trips differed significantly between the first and the third study week among the intervention and control groups. The Mann–Whitney U test results suggest an insignificant difference, meaning the active information sharing did not significantly promote healthier travel behavior in our study. This unexpected result may be explained by (1) limited explainable power of a small-size sample and (2) cold weather during the study period that might discourage possible behavior change. Nonetheless, results from the web-based Exit Survey indicated that participating in a study about health impacts of travel behavior led to augmented awareness of travel behavior, travel-related physical activity, and travel-related well-being effects.

Feedback from participants suggests their high satisfaction with the study experience. Participants spoke highly of the organization of the field study (e.g., orientation meeting and information provided) and the compensation provided. Additionally, participants confirmed the advantage of a smartphone in terms of its instant documenting ability and portability, and that they preferred reporting their travel information through a phone-based survey rather than a pen-and-paper instrument. With respect to privacy issues, our experience suggests that quality communication with the participants and guaranteed confidentiality ease participants' concerns.

To conclude, UbiActive is an adaptive, smartphone-based application that enables auto tracing and context-aware experience sampling. It allows researchers to collect in situ information and interactive communication between users and researchers. It could be applied in various research settings, such as transportation, clinical trials, emergency medical services, etc. Future improvement areas for this study include better trip detection, better energy expenditure estimation, and reduced battery consumption for UbiActive, as well as new intervention designs that go beyond simple information sharing.



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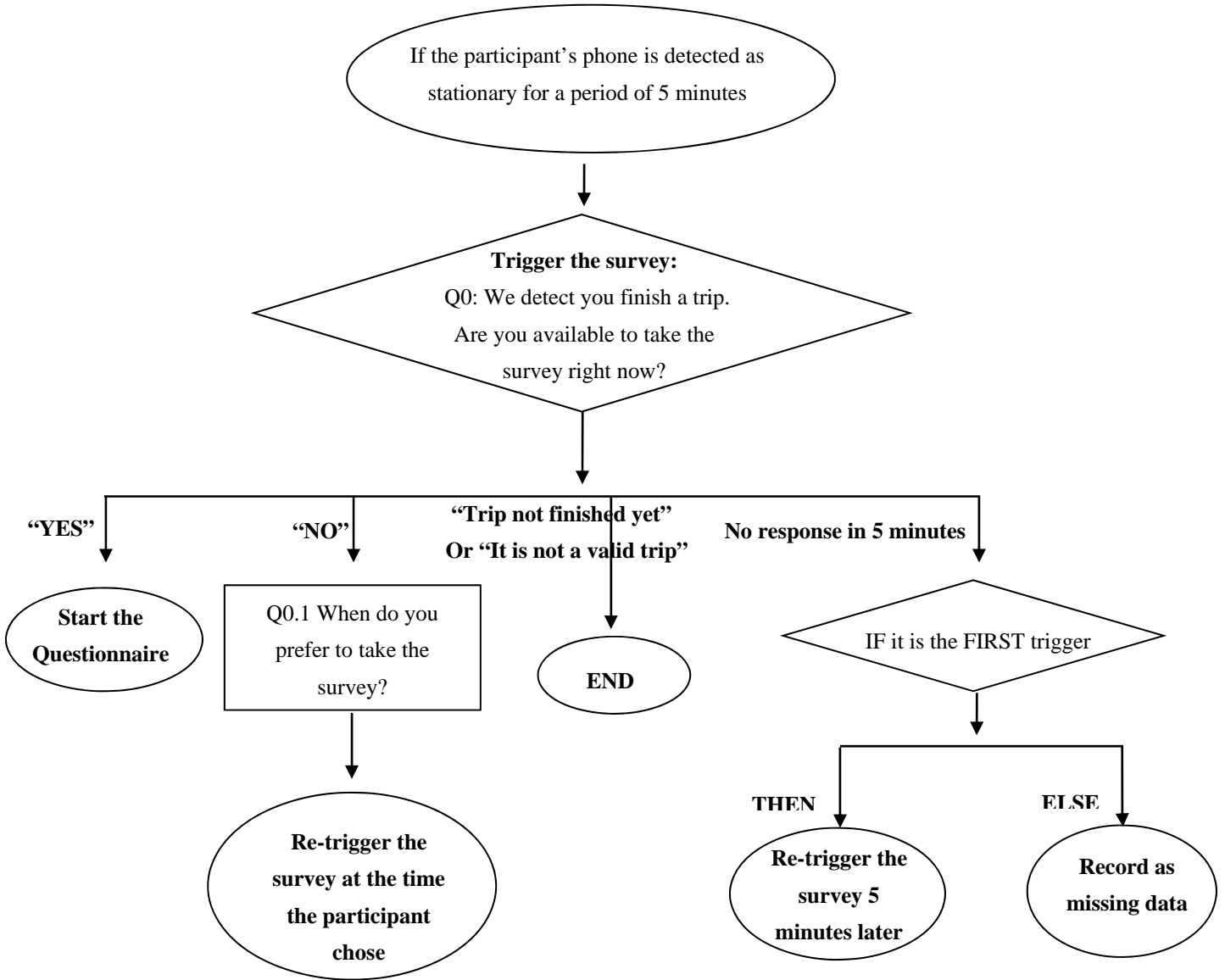
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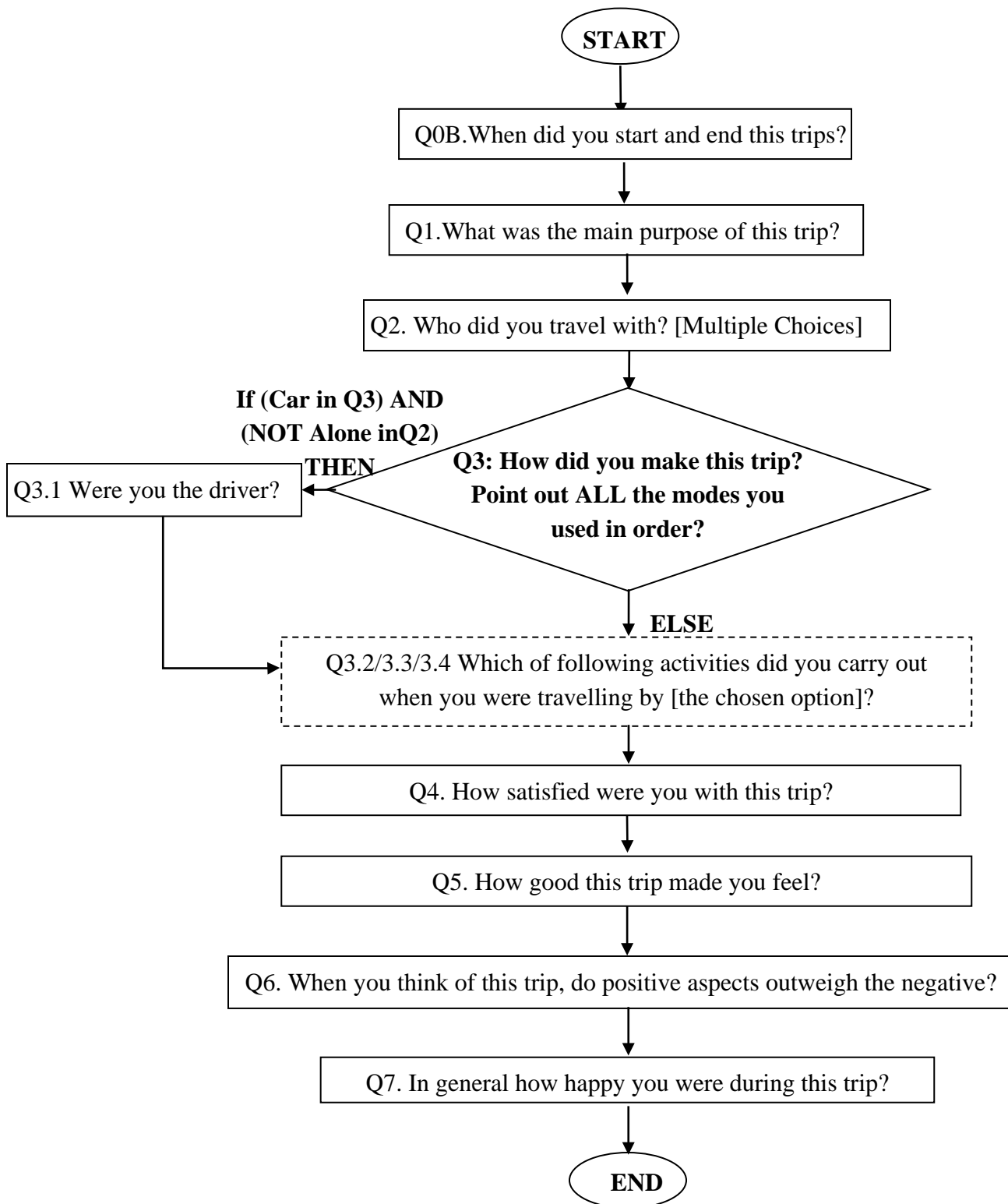
**APPENDIX A**  
**SMARTPHONE-BASED SURVEY TRIGGERING PROCESS**





**APPENDIX B**  
**SMARTPHONE-BASED SELF-REPORTED QUESTIONNAIRE**

## Flowchart



*Questionnaire*

**Q0A. We detect you just finished a trip. Are you available to take the survey right now?**

- (A) Yes (Skip to Question Q1)
- (B) No (Ask Question Q0.1)
- (C) Trip not finished yet (Stop sending the questions)
- (D) It is not a valid trip (Stop sending the questions)

**Q0.1 When do you prefer to take the survey?**

- (A) 5 minutes later
- (B) 10 minutes later
- (C) 20 minutes later
- (D) 30 minutes later
- (E) 45 minutes later
- (F) 60 minutes later

**Q0B. What time did you start and end this trip?**

Start at \_\_\_\_\_:\_\_\_\_\_ End at \_\_\_\_\_:\_\_\_\_\_

**Q1. What was the main purpose of this trip?**

- (A) Return home
- (B) Work-related
- (C) School-related
- (D) Transport someone
- (E) Shopping/errands
- (F) Meals- or eating-related
- (G) Recreation/fitness activity
- (H) Socializing/hang out
- (I) Civic/religious activities
- (J) Family or personal business/obligations
- (K) Other

Note: this question is revised based upon National Household Transportation Survey.

<http://nhts.ornl.gov/tables09/CodebookBrowser.aspx>

**Q2. Who did you travel with? [Multiple Choices: check all that apply]**

- (A) Alone
- (B) Friends/schoolmates/neighbors/acquaintances
- (C) Co-workers/colleagues/clients
- (D) Spouse/ unmarried partner
- (E) Children under age 12
- (F) Children age 12 or older
- (G) Other family member
- (H) Other

Note: this question is revised based upon American Time Use Survey. <http://www.bls.gov/tus/documents.htm>

**Q3. How did you make this trip? Point out ALL the modes you used in order?**

- (A) Walking (Skip to Question Q3.2)
- (B) Bicycle (Skip to Question Q3.3)
- (C) Car (Ask Question Q3.1)
- (D) Bus (Skip to Question Q3.4)
- (E) Train/Subway (Skip to Question Q3.4)
- (F) Taxi (Skip to Question Q3.4)
- (G) Other (Skip to Question Q3.4)

Note: this question is revised based upon Computer-Based Intelligent Travel Survey System: CASI/Internet Travel Diaries with Interactive Geocoding. Resource Systems Group, Inc <http://www.fhwa.dot.gov/ohim/trb/rsg rpt.pdf>

**Q3.1 Were you the driver?**

- (A) Yes (Skip to Question Q3.3)
- (B) No (Skip to Question Q3.4)

**Q3.2 Which of following activities did you carry out when you were travelling by [the chosen option]? [Multiple Choices: check all that apply]**

- (A) Talking/Conversation/Making Phone Call
- (B) Listening to the Radio/Music
- (C) Relaxing/Thinking/Smoking
- (D) Using mobile device for work
- (E) Using mobile device for entertainment
- (F) Meals/Snacks/Drinks
- (G) Other

**Q3.3 Which of following activities did you carry out when you were travelling by [the chosen option]? [Multiple Choices: check all that apply]**

- (A) Talking/Conversation/Making Phone Call
- (B) Listening to the Radio/Music
- (C) Relaxing/Thinking/ Smoking
- (D) Meals/Snacks/Drinks
- (E) Other

**Q3.4 Which of following activities did you carry out when you were travelling by [the chosen option]? [Multiple Choices: check all that apply]**

- (A) Talking/Conversation/Making Phone Call
- (B) Listening to the Radio/Music
- (C) Relaxing/Thinking/Resting/Smoking
- (D) Reading
- (E) Using mobile device for work
- (F) Using mobile device for entertainment
- (G) Meals/Snacks/Drinks
- (H) Other

**Q4. How satisfied were you with this trip?**

Completely unsatisfied ←-----→ Completely satisfied

1 2 3 4 5

**Q5. How good did this trip make you feel?**

Not good at all ←-----→ Very good

1 2 3 4 5

**Q6. When you think of this trip, do positive aspects outweigh the negative?**

Negative aspects outweigh positive ←-----→ Positive aspects outweigh negative

1 2 3 4 5

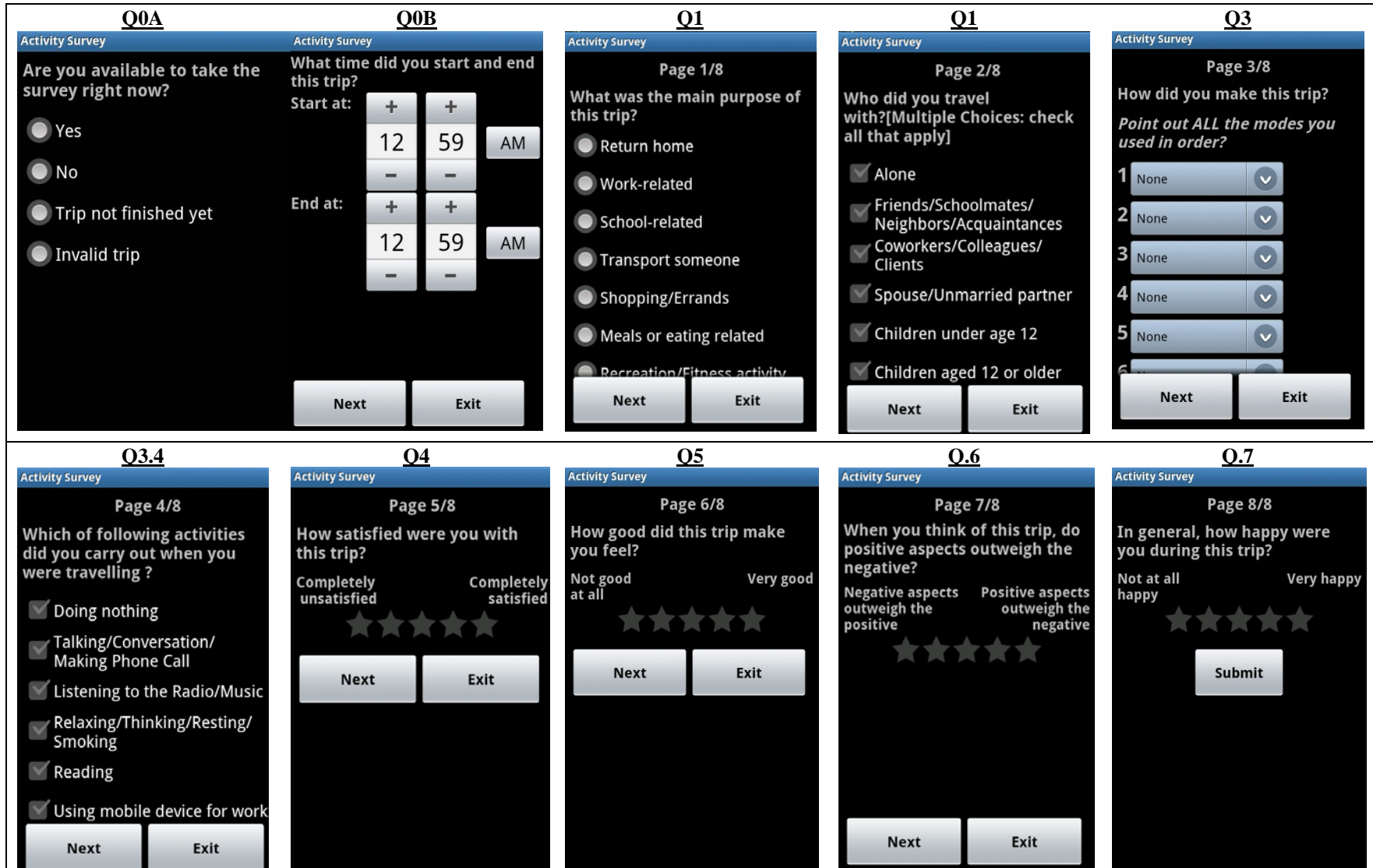
**Q7. In general, how happy were you during this trip?**

Not happy at all ←-----→ Very happy

1 2 3 4 5

Note: for all well-being related questions (Q4-Q7), please refer to Appendix C for related literature and selection reasons.

Screenshots



**APPENDIX C**  
**SUMMARY OF RELATED SUBJECTIVE WELL-BEING QUESTIONS**



In general, subjective well-being (SWB) is defined as the degree to which an individual positively evaluates the overall quality of their lives. Diener et al. (1985) posits that SWB consists of three components, positive affect (PA) and negative affect (NA) related to immediate experiences, and a cognitive component consisting of a judgment of satisfaction with life as a whole.

ID	Measure Name	Question Used	Source
1	Satisfaction with Travel Scale (STS)	<p>Measure satisfaction with daily travel without focusing on any particular travel mode. A principal component analysis with varimax rotation resulted in retention of the following five statements with high loadings on the same factor:</p> <ul style="list-style-type: none"> <li>◆ I am completely satisfied with my daily travel</li> <li>◆ My travel facilitates my daily life</li> <li>◆ When I think of my daily travel the positive aspects outweigh the negative</li> <li>◆ I do not want to change anything regarding my daily travel</li> <li>◆ My daily travel makes me feel good</li> </ul> <p>Respondents rated the statements on seven point Likert scales ranging from 0 (do not agree) to 6 (agree completely).</p>	<p>Author: Cecilia Jakobsson ergstad, Amelie Gamble, Tommy Gärling, Olle Hagman, Merritt Polk, Dick Ettema, Margareta Friman and Lars E. Olsson            Title: Subjective Well-being Related to Satisfaction With Daily Travel            Date: 27 May 2010            Web link:  <a href="http://www.springerlink.com/floyd.lib.umn.edu/content/1640435310v66k4v/">http://www.springerlink.com/floyd.lib.umn.edu/content/1640435310v66k4v/</a></p>
2	Swedish Core Affect Scale (SCAS)	<p>Measure past affective subjective well-being or current mood. The short version of Swedish Core Affect Scale (SCAS). Retrospectively measure what affect respondents felt while performing each of the activities they had performed at least once during previous week. Ratings were made of <i>valence (unpleasantness–pleasantness)</i> and <i>activation (quietness–excitement)</i> using two seven-point scales ranging from 0 to 6. (See Appendix A and B)</p> <p>The end-points of the <i>valence</i> scale were defined by the three adjectives <i>sad, dissatisfied, depressed</i> and <i>glad, satisfied, joyful</i>, respectively, and the end-points of the <i>activation</i> scale <i>sleepy, passive, dull</i> and <i>awake, active, alert</i>, respectively.</p> <p>The full version has 12 pairs of end-points instead of 3 pairs for valence and activation (See Appendix A). If an activity had been performed more than once, the respondents were asked to rate the most frequent affect associated with the activity.</p>	<p>Author: Daniel Västfjäll, Margareta Friman, Tommy Gärling, Mendel Kleiner            Title: The Measurement of Core Affect: A Swedish Self-Report Measure Derived from the Affect Circumplex            Date: Mar 22, 2002            Web Link:  <a href="http://onlinelibrary.wiley.com/floyd.lib.umn.edu/doi/10.1111/1467-9450.00265/abstract">http://onlinelibrary.wiley.com/floyd.lib.umn.edu/doi/10.1111/1467-9450.00265/abstract</a></p>
3	Satisfaction with	A Satisfaction with Activities Scale (SAS) was constructed for each	Author: Cecilia Jakobsson

	Activities Scale (SAS)	respondent by first averaging the valence and activation ratings for each activity, then averaging across all the performed activities (ranging from 1 to 9 different activities with a mean of 4.5).	Bergstad, Amelie Gamble, Tommy Gärling, Olle Hagman, Merritt Polk, Dick Ettema, Margareta Friman and Lars E. Olsson Title: Subjective Well-being Related to Satisfaction With Daily Travel Date: 27 May 2010 Web link: <a href="http://www.springerlink.com/floyd.lib.umn.edu/content/1640435310v66k4v/">http://www.springerlink.com/floyd.lib.umn.edu/content/1640435310v66k4v/</a>
4	Satisfaction with Life Scale (SWLS)	SWLS can be considered as a measure of cognitive subjective well-being, which consists of an average of the following 5 statements rated on seven-point Likert scales ranging from 0 (do not agree) to 6 (completely agree): <ul style="list-style-type: none"> <li>◆In most ways my life is close to my ideal</li> <li>◆The conditions of my life are excellent</li> <li>◆I am satisfied with my life</li> <li>◆So far I have achieved the important things I want in life</li> <li>◆If I could live my life over again, I would change almost nothing</li> </ul>	Author: Diener, Ed, Emmons, Robert A., Larsen, Randy J., Griffin, Sharon Title: The Satisfaction With Life Scale Date: 26 Mar 2002 Web link: <a href="http://web.ebscohost.com/floyd.lib.umn.edu/ehost/detail?hid=12&amp;sid=5bcf4fb7-5c0d-4fda-9d18-f8ac879224f4%40sessionmgr11&amp;vid=1&amp;bdata=JnNpdGU9ZWWhvc3QtbGl2ZQ%3d%3d#db=s3h&amp;AN=6385463">http://web.ebscohost.com/floyd.lib.umn.edu/ehost/detail?hid=12&amp;sid=5bcf4fb7-5c0d-4fda-9d18-f8ac879224f4%40sessionmgr11&amp;vid=1&amp;bdata=JnNpdGU9ZWWhvc3QtbGl2ZQ%3d%3d#db=s3h&amp;AN=6385463</a>
5	Positive and Negative Affect Schedule Scale (PANAS)	This scale consists of 20 words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent [INSERT APPROPRIATE TIME INSTRUCTIONS HERE]. Use the following scale to record your answers:  1-very slightly or not at all 2-a little 3-moderately 4-quite a bit 5-extremely	Author: Watson, David; Clark, Lee A.; Tellegen, Auke Title: Development and validation of brief measures of positive and negative affect: The PANAS scales Date: 1988 Web link: <a href="http://psycnet.apa.org/floyd.lib.umn.edu/index.cfm?fa=search.displayRecord&amp;uid=1988-31508-001">http://psycnet.apa.org/floyd.lib.umn.edu/index.cfm?fa=search.displayRecord&amp;uid=1988-31508-001</a>

		<p><b>10 descriptors for the positive affect (PA) scale:</b> <i>attentive, interested, alert, excited, enthusiastic, inspired, proud, determined, strong and active.</i></p> <p><b>10 descriptors for the Negative affect (NA) scale:</b> <i>distressed, upset (distressed); hostile, irritable (angry); scared, afraid (fearful); ashamed, guilty (guilty); and nervous, jittery (jittery).</i></p> <p>We have used PANAS with the following time instructions:</p> <ul style="list-style-type: none"> <li>◆ Moment (you feel this way right now, that is, at the present moment)</li> <li>◆ Today (you have felt this way today)</li> <li>◆ Past few days (you have felt this way during the past few days)</li> <li>◆ Week (you have felt this way during the past week)</li> <li>◆ Past few weeks (you have felt this way during the past few weeks)</li> <li>◆ Year (you have felt this way during the past year)</li> <li>◆ General (you generally feel this way, that is, how you feel on the average)</li> </ul>	
6	Single item question for cognitive SWB	<p>Rate on 10-point Likert scale ranging from 1 (dissatisfied) to 10 (satisfied):</p> <ul style="list-style-type: none"> <li>◆ All things considered, how satisfied are you with your life these days?</li> </ul> <p>Rate on 4-point Likert scale ranging from 1 to 4: 1-very happy 2-quite happy 3-not very happy 4-Not at all happy</p> <ul style="list-style-type: none"> <li>◆ Taken all together, would you say that you are very happy, pretty happy, or not too happy?</li> </ul>	<p>World Values Survey Date: 2005 Web link: <a href="http://www-bcf.usc.edu/~easterl/papers/Happiness_and_Growth_Appendix.pdf">http://www-bcf.usc.edu/~easterl/papers/Happiness and Growth Appendix.pdf</a></p>

**APPENDIX D**  
**GENERAL BACKGROUND INFORMATION SURVEY**

## Page #1 : Introduction

### Introduction



- ***THIS SURVEY INCLUDES 24 BACKGROUND QUESTIONS AND WILL TAKE ABOUT 10 MINUTES.***
- ***THIS INFORMATION WILL HELP US UNDERSTAND YOUR ELIGIBILITY FOR PARTICIPATING IN OUR RESEARCH.***
- ***ALL OF YOUR ANSWERS WILL BE KEPT STRICTLY CONFIDENTIAL.***



**1. Email Address:**

This is just for communication, and we will NOT use this email for any other purposes.

**2. Zip Code of your home address: (e.g. 55414)**

Next

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**Page #2 : Eligibility Confirmation – Part 1**

Smartphone Project Background Information Survey

Exit this survey

Eligibility Confirmation



***PLEASE CONFIRM THE FOLLOWING TO ENSURE YOU ARE ELIGIBLE TO PARTICIPATE:***

**3. You have NOT worked for any survey research institution?**

- True
- False

**4. You have NOT participated in any research about physical activity or travel behavior in the past six months?**

- True
- False

**5. You are between the age of 18 and 35?**

- True
- False

**6. In what year were you born? (e.g. 1987)**

**Page #2 : Eligibility Confirmation – Part 2**

7. You do NOT have any health problems, conditions, or disabilities that would prevent you from engaging in travel behavior such as walking or biking?

- True  
 False

8. You own an Android phone?

- True  
 False

9. What brand is your Android phone? (e.g. Samsung Infuse 4G, Motorola Droid 3, etc.)

10. What's the firmware version of your Android phone? (e.g. 2.3.6).

You can find this information by looking into "About Phone" option in "Setting" menu. This information might be named as "Android Version" as well.

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**Page #3 Personal Attributes – Part 1**

Personal Attributes



**11. What is your gender?**

- Male
- Female

**12. Are you of Hispanic, Latino, or Spanish origin?**

- Yes
- No

**13. Which of the following racial groups best describe your race?**

- White Only
- Black or African-American only
- Asian only
- American-Indian only
- Multiracial
- Other



**Page #3 Personal Attributes – Part 2**

**14. Which of the following occupations most accurately describes you?**

- Full-time undergraduate student
- Part-time undergraduate student
- Full-time graduate or professional student
- Part-time graduate or professional student
- Faculty
- Staff
- Alumni
- Other

**15. What was your household's total income in 2010, before taxes?**

- Less than \$10,000
- \$10,000 - \$24,999
- \$25,000 - \$49,999
- \$50,000 - \$74,999
- \$75,000 - \$99,999
- \$100,000 or more

**16. How many people are currently living in your house?**

- 1
- 2
- 3
- 4
- 5 or more

## Page #3 Personal Attributes – Part 3

Smartphone Project Background Information Survey

Exit this survey

### Personal Attributes



17. Are you living with children under 18?

- Yes
- No

18. Are you living with spouse or unmarried partner?

- Yes
- No

19. How many vehicles are owned, leased, or available for regular use by the people who currently live in your household?

- 0
- 1
- 2
- 3
- 4 or more

Prev

Next

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## Page #4 Self-Reported Health

Smartphone Project Background Information Survey

Exit this survey

### Self-Reported Health



20. What's your height and weight? Rough estimates are completely OK. Please indicate both the number and unit.

Height(e.g.5 feet 3 inches)

Weight(e.g.120 pound)

21. On a scale of 1 to 5, how would you rate you overall health?

	1-Poor	2	3	4	5-Excellent
Overall Health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Prev

Next

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Travel Behavior



**22. Last week, for work-related/school-related commute trips, which mode did you use most frequently?**

- Walking
- Bicycle
- Car
- Bus
- Train/Subway
- Taxi
- Other

**23. Last week, for non-work/non-school trips, which mode did you use most frequently?**

- Walking
- Bicycle
- Car
- Bus
- Train/Subway
- Taxi
- Other

**Page #5 Travel Behavior – Part 2**

**24. On a scale of 1 to 5, how are the following factors a issue for you to make more walking or biking trips?**

	1- Not an issue	2	3	4	5- A serious issue	Not applicable
The distance between origins and destinations?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The amount of traffic along the route?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The speed of traffic along the route?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
You have too many things to carry?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
You have small children along?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Violence or crime along the route?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor weather or climate in your area?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Prev

Next

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**Page #5 Survey Completed**

Smartphone Project Background Information Survey

Exit this survey

Survey Completed



***THIS IS THE FINAL PAGE. PLEASE CLICK "DONE".***

***THANK YOU VERY MUCH FOR COMPLETING THE SURVEY! WE WILL CONTACT YOU SOON VIA EMAIL.***



Prev

Done

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**APPENDIX E**  
**INFORMATION SHEET FOR RESEARCH PARTICIPANTS IN THE**  
**INTERVENTION GROUP**

## INFORMATION SHEET FOR RESEARCH PARTICIPANTS

Thank you for your interest in this research which investigates how smartphones can be used to study travel-related physical activity and psychological experiences. Please read this form and ask any questions you may have before participating in this research.

### **Project Introduction:**

This research is conducted by researchers from the Humphrey School of Public Affairs and the Minnesota Traffic Observatory, University of Minnesota. In this research, we apply advanced smartphone technologies including computing, communication, and sensing to collect momentary information about people's daily travel behavior as well as physical activity and psychological experiences associated with their daily travel. Findings from this research are expected to shed light on the potential of smartphone applications for understanding travel-related physical activity and well-being effects as well as for promoting healthy travel behavior changes.

### **Participants' Responsibility:**

If you agree to participate, please perform the following tasks:

1. **Allow researchers to install our application named UbiActive on your phone.** The UbiActive application is designed by our researchers.
2. **Wear your phone—with our application running—on your right hip by means of a carrying case during all waking hours other than during water activities for three consecutive weeks.** Our researchers will provide you a carrying case for your phone in the information session.

**IMPORTANT:** Please ensure that your phone is carried on your right hip for as much time as possible. The built-in-accelerometer in Android phones will not provide accurate detection of physical activity if the phone is not in close contact with body center. Not carrying your phone on the right hip will result in invalid physical activity data and inconsistent data across participants.

3. **Respond to a set of questions on your Android phone when signaled by vibration.** Vibration will occur about 5 minutes after you make any trip that is longer than 10 minutes. Trips shorter than 10 minutes are not detected by our application. Each vibration signals a triggered survey for you to respond on your Android phone. Each survey includes nine questions about how you made the trip and how you felt about the trip. Please answer all questions in each survey. Each survey should take you less than two minutes to complete.

**IMPORTANT:** If you miss the first vibration signal which occurs about 5 minutes after a trip, a second vibration signal will occur about 10 minutes after the trip to give you another chance to take the survey. If you cannot respond to the survey at the time



it is triggered, you could answer “NO” to the first survey question “Are you available to take the survey right now?” and have the option to select your preferred time to respond to the survey.

**IMPORTANT:** Due to internal phone issues, there will be times that the application fails to send you any vibration signals after completion of eligible trips<sup>1</sup>. In this case—that is, when no vibration signals occur within 10 minutes from the completion of an eligible trip—you are required to manually trigger the survey on your phone and complete the survey by simply clicking the App named “Activity Survey” and answering questions in the App.

**IMPORTANT:** There will also be times that the application sends your vibration signals in the middle of a trip or way beyond 10 minutes after completion of a trip<sup>2</sup>. In these cases, please answer “Trip not finished yet” or “This is an invalid trip” to the first survey question to end the survey.

- 4. Fill out the paper-version daily travel diary booklet** to record every longer-than-10-minute trip you make during the three consecutive weeks of participation and record if our application is able to detect these trips.

**IMPORTANT:** Please record every longer-than-10-minute trip you make. Information you provided through this travel diary booklet is extremely helpful for us to further calibrate and improve the performance of our application.

- 5. Read the daily report sent to you on each day of your second participation week.** Around 11pm on each day of your second participation week, you will receive a daily report displayed on your phone summarizing your travel-related physical activity and psychological experiences. Please read these daily reports.

**IMPORTANT:** On any day of your participation, do not connect your phone to the computer between 10pm to midnight. In fact, we advise you to avoid connecting phone to computer as much as possible. This is because USB connection of your phone to computer may block our application from running and result in invalid data. Charging the phone to a power outlet is OK and does not interfere with our application.

---

<sup>1</sup> Eligible trips are trips longer than 10 minutes.

<sup>2</sup> The application is design to send you the first vibration signal about 5 minutes after completion of an eligible trip, and send you the second vibration signal about 10 minutes after trip completion if you missed the first signal.

**Compensation:**

You will receive up to \$100 as compensation for your participation in this research. The compensation amount is dependent upon the number of days you manage to wear your phone properly and produce valid data:

- **\$100:** if you wear your phone properly<sup>3</sup>, complete at least 70% of the phone-triggered surveys, and fill out the paper-version travel diary for at least **FOUR DAYS A WEEK** (including at least one weekend day) during the three weeks of participation.
- **\$ 75:** if you wear your phone properly, complete at least 70% of the phone-triggered surveys, and fill out the paper-version travel diary for at least **THREE DAYS A WEEK** (including at least one weekend day) during the three weeks of participation.
- **\$ 50:** if you wear your phone properly, complete at least 70% of the phone-triggered surveys, and fill out the paper-version travel diary for at least **TWO DAYS A WEEK** (including at least one weekend day) during the three weeks of participation

After your three-week participation, a wrap-up session will be hosted to gather data stored in your smartphone and your contact information. You will be contacted within a week of the wrap-up session to pick up your compensation at a location on campus. We could also mail the compensation check to your address should you desire.

**UbiActive's Impacts on Phone Performance:**

We have tested the impact of our application on phones' battery life, memory requirement, and network usage.

- With the application running in the background continuously, the battery life of a phone is likely to be 8-10 hours with normal voice/text/data usage. It is important to note that the impact on the battery life varies by phone and depends on your own way of usage.
- The application collects about 7MB of raw sensor data and statistics per day which will be stored in the memory card of your phone. Therefore, for three weeks of participation, 150Mb storage space is needed.
- The application sends summaries of your activity to our server at the end of each week. This will consume about 40KB of your network usage. The total impact of this application on network usage is minimal—less than 1MB for the whole three-week period.

---

<sup>3</sup> That is, carry your phone on your right hip using the phone case provided by us.

**Confidentiality:**

Information collected by our application includes location data (i.e., latitude and longitude), activity data (i.e., speed and acceleration), and other self-reported travel information (i.e., start and end time, trip mode, companion, secondary activities, and experience). All the collected information will be encrypted and stored on a server behind a firewall. In any report we might publish, we will not include any information that will make it possible to identify you.

**Voluntary Nature of the Study:**

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota.

**Contacts and Questions:**

The Principal Investigator for this study is Assistant Professor Yingling Fan at the Humphrey School of Public Affairs. Other researchers conducting this study include: Chenfu-Liao (co-investigator), Frank Douma (co-investigator), Qian Chen (research assistant), and Sowmya Ramesh (research assistant). You are encouraged to contact us via [smtphone@umn.edu](mailto:smtphone@umn.edu) or leave comments at our website <http://z.umn.edu/smartphone> should you have any questions about the project.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

*You will be given a hard copy of this information sheet for your record purpose.*

**APPENDIX F**  
**DOS AND DON'TS SHEET FOR PARTICIPANTS IN THE INTERVENTION**  
**GROUP**

## DO's and DON'T's

### DO:

- **Do charge your phone every night and when the battery is low.** Our application runs in the background continuously, which leads to short battery life (8-10 hours). Make sure your phone is fully charged every morning and has power during the day because the application does not collect any data when the phone is powered off.
- **Do place your phone on your right hip using the provided carry case during all waking hours except survey time, phone call time, and water activity time.** This wearing location ensures the physical activity data collected by our application to be valid and consistent for comparison between participants. All waking hours includes exercise, work, school, entertainment, social, dining, and etc.
- **Do manually trigger a survey and complete the survey if you do not receive any vibration signal within 10 minutes of a completed trip.** To manually trigger the survey, simply click the App named "Activity Survey".
- **Do carry the paper-version travel diary booklet with you every day, record every trip that is longer than 10 minutes, and report if our application successfully detects the trips.** This information will help us further calibrate and improve our application.
- **Do check the GPS flashing icon occasionally.** No icon flashing indicates that our application may have stopped running. If the icon stops flashing for more than an hour, contact us at your earliest convenience at [smtphone@umn.edu](mailto:smtphone@umn.edu).
- **Do contact us at your earliest convenience at [smtphone@umn.edu](mailto:smtphone@umn.edu) if there is problem with our application.** For example, for a day, the application always fail to trigger after-trip surveys or fail to trigger surveys properly—within the 10-minute time window.
- **Do read the daily report sent to you on each day of your second participation week.** Around 11pm on each day of your second participation week, you will receive a daily report displayed on your phone summarizing your travel-related physical activity and psychological experiences. Please read these daily reports.

### DON'T:

- **Don't turn off your GPS or Vibration settings.** The GPS and vibration setting have to be turned ON to detect trips and send you survey signals.
- **Don't connect your phone to computer or laptop between 10 pm to midnight.** In fact, we advise you to avoid connecting phone to computer as much as possible. This is because USB connection of your phone to computer may block our application from running and result in invalid data.
- **Don't click or uninstall any of the following Apps installed on your phone: Sensor Data, Daily Report, Weekly Report, and Weekly Comparison Report.** This is to avoid possible malfunction of these Apps.

**ADDITIONAL TIPS FOR COMPLETING SURVEYS ON THE PHONE:**

- **How to go to the next question:** Click "Next" on the survey page.
- **How to go back to the last question:** Click the Back button on your phone (this button is on your phone NOT on our survey page. The button should look like an arrow toward left).
- **How to quit the survey:** click "Exit" on the survey page.
- **DON'T click the Home button on your phone during the survey:** If you click the Home button, the survey would be forced to close and none of your inputs will be recorded.

**APPENDIX G**  
**TRAVEL DIARY BOOKLET EXAMPLE**

Day 1: <u>10</u> (month) <u>28</u> (date) <u>2011</u> (year) <span style="float: right;"><i>11: 00 p.m. the previous day to 11: 00 p.m. the diary recorded day</i></span>						
What TIME did you start and end each trip?		HOW did you Travel?	What is the PURPOSE of this trip?	You did RECEIVE the auto-triggered after-trip survey.	You did NOT RECEIVE the auto-triggered after-trip survey.	Remark
Start:	End:			WHEN did you receive the prompt?	WHEN did you self-trigger the survey?	
<i>Example 1:</i> 2: 00 pm	2: 55 pm	walk, bus, walk	School	3: 00 pm		The trip was detected correct
<i>Example 2:</i> 5: 30 pm	5:45 pm	walk, bike, walk	School		5:57pm	Didn't notice the prompt
<i>Example 3:</i> 6: 30 pm	6:50pm	car	Go home			No prompt and too busy to self-trigger a survey
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
Other Comments:						



**APPENDIX H**  
**SCREENSHOTS OF WEB-BASED EXIT SURVEY**

## Page #1 : Introduction



- All information collected in this survey will be kept confidential.
- You will receive a \$20 Target gift card after completion of this post-study survey.
- The \$20 gift card is a separate reward in addition to the compensation you receive for your three weeks of study participation.
- The compensation for your three-week participation has been determined based upon the data collected on your phone.

**1. Please enter your email address to access our survey questions.**

**2. How do you prefer to get the \$20 Target gift card?**

- Campus pick up
- Mail to me

If you choose "Mail to me", please specify your mailing address:

Next

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Section 1: Your Participation Experience



3. Overall, how satisfied are you with your participation in this study?

- Very satisfied
- Satisfied
- Somewhat satisfied
- Not satisfied

4. Specifically, how satisfied are you with each of the following study components?

	Very satisfied	Satisfied	Somewhat satisfied	Not satisfied
The smartphone application's ability to detect trips	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The smartphone application's user interface for after-trip surveys	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The design/layout of the paper-based travel diary booklet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The orientation meeting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The information packet provided to you (e.g., the project summary, Do's & Don't Do's sheet)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The level of communication with the researchers during the participation weeks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The amount of compensation offered	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Page #2 : Participation Experience – Part 2**

**5. Specially, how disruptive was each of the following participation requirements to your everyday life?**

	Very disruptive	Disruptive	Somewhat disruptive	Not disruptive
Charge your phone everyday or whenever the battery is low	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wear your phone in close contact with your body center (either on your hip or in your pant pocket)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fill out the smartphone-based after-trip surveys	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Manually trigger after-trip surveys when the phone fails to detect a trip.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Record each of your trips in the paper-based travel diary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Avoid accessing the mass storage of your phone between 10pm to mid-night	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keep GPS setting always on	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keep vibration setting always on	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Read the weekly reports at the end of each week and the daily reports in the second week	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**6. How often were you able to do each of the following during your participation weeks?**

	Always or almost always	Most times (more than half the time)	Sometimes (about half the time)	A few times (less than half the time)	Almost never or never
Keep your phone powered on	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wear your phone in close contact with your body center	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fill out the smartphone-based after-trip surveys	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Manually trigger after-trip surveys when the phone fails to detect a trip	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Record each of your trips in the paper-based travel diary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Avoid accessing the mass storage of your phone between 10pm to mid-night	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keep GPS setting always on	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keep vibration setting always on	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Read the weekly reports at the end of each week and the daily reports in the second week	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Page #2 : Participation Experience – Part 3**

**7. Please describe situations that had prevented you from meeting each of the following requirements.**

Situations preventing you from keeping phone powered on:

Situations preventing you from wearing phone properly:

Situations preventing you from filling out the smartphone-based surveys:

Situations preventing you from manually triggering surveys:

Situations preventing you from recording trips in travel diary:

Situations preventing you from avoiding accessing the mass storage of your phone between 10pm to mid-night:

Situations preventing you from keeping GPS setting always on:

Situations preventing you from keeping vibration setting always on:

Situations preventing you from reading the weekly and daily reports:

**8. Did your participation in this study make you more aware of the following?**

	Completely	A great deal	Somewhat	Not at all
Make you more aware of your travel behavior	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make you more aware of your travel experience and well-being	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make you more aware of your travel-related physical activity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**9. Did your participation in this study lead to any changes in your travel behavior?**

- Yes
- No

If YES, please specify the changes in your travel behavior:

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Section 2: Smartphone Application in Particular



**10. How long is your average battery life WITHOUT our application installed? Please enter a positive integer.**

Unit: Hour

**11. How long is your average battery life WITH our application installed? Please enter a positive integer.**

Unit: Hour

**12. Out of all the longer-than-10-minute trips you made during the three weeks of participation, for what percentage of these trips you were able to receive automatically triggered after-trip surveys? (A rough estimate is OK. Please enter a positive integer.)**

Unit: %

**13. How long did it typically take you to receive the automatically triggered survey after each trip?**

- Within 5 minutes after your trips
- Within 5-10 minutes after your trips
- Within 10-20 minutes after your trips
- Within 20-30 minutes after your trips
- None of the above

If none of the above, please describe your experience:

**14. Did you feel that the accuracy of trip detection varies by the kind of trips you made? (e.g., depending upon the transportation mode of the trip; whether the origins/destinations are open spaces, underground facilities; the way you wear the phone, etc.)**

- Yes
- No

If YES, please specify your experience:

**Page #3 : Smartphone Application in Particular – Part 2**

**15. Did you have any experience receiving automatically-triggered surveys when you hadn't made any trips at all?**

- Yes
- No

If YES, please describe the situation and frequency that these wrongly prompted surveys occur

**16. In the second week of your participation, how many days did you receive the daily reports? Please enter an integer.**

Unit: Day

**17. How many weekly reports did you receive in total?**

**18. Do you agree or disagree with each of the following statements about the daily and weekly reports?**

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree
The information provided in the reports is about right (not too little or too much)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The information provided in the reports is useful and interesting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The information provided in the reports is easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The information provided in the reports makes sense (e.g., matches up with your physical activity level and/or trip experience)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**19. Please provide suggestions to help us further improve the daily and weekly reports. (e.g., additional information to be included, wording changes, changes in the report provision timing, etc.)**



**Page #3 : Smartphone Application in Particular – Part 3**

20. Please describe strengths and qualities of our smartphone application that impressed you most. (e.g., ability to detect trip, ability to measure physical activity levels, etc.)

21. Please describe weaknesses and problems of our smartphone application that bothered you most. (e.g., influence on battery length, invalid trip detection, survey triggering or re-triggering failure, etc.)

22. Please provide suggestions to help us further improve this smartphone application.

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**Page #4 : Design of the After-Trip Survey & Travel Diary Booklet – Part 1**



**23. Do you agree or disagree with each of the following statements about the phone-based after-trip surveys? Our after-trip survey includes a total of 9 questions. A list of the questions can be found at: <http://blog.lib.umn.edu/cliao/smartphone/2011/12/smartphone-based-activity-survey.html>**

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree
The number of questions in the after-trip survey is about right (not too many)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The after-trip survey is easy to navigate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Questions in the after-trip survey are easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Answer options in the after-trip survey are reasonable and easy to pick	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**24. Please provide suggestions to help us further improve the after-trip survey design. (E.g., additional questions to be included, changes of questions wording, etc. )**

## Page #4 : Design of the After-Trip Survey & Travel Diary Booklet – Part 2

25. Do you agree or disagree with each of the following statements about the travel-diary booklet? Our travel diary booklet includes a total of 5 questions. A copy of the travel diary booklet can be found at: [http://blog.lib.umn.edu/cliao/smartphone/assets\\_c/2011/12/diary-106495.html](http://blog.lib.umn.edu/cliao/smartphone/assets_c/2011/12/diary-106495.html)

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree
The amount of information asked in the travel-diary booklet is about right (not too much)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The travel-diary booklet is easy to navigate and fill out	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

26. Please provide suggestions to help us further improve the travel diary booklet? (E.g., additional questions to be included, formatting changes, changes in the wording of the instructions, etc.)

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## Page #5 : Privacy Issues & General Concerns – Part 1

Smartphone Project Post-study Survey\_A

Exit this survey

### Section 4: Privacy Issues & General Concerns



**27. How long had you used a smartphone prior to participating in this study? (Please enter an integer. If this was your first experience using a smartphone, please enter "0")**

Unit: Month

**28. How often do you use mapping apps on your smartphone to get travel directions and/or locational information?**

- Frequently
- Occasionally
- Rarely
- Never

**29. Do you agree or disagree with each of the following statements regarding use of the smartphone as a data collection instrument?**

	Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree
I felt comfortable having smartphone tracking my locations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I felt comfortable having smartphone detecting my general travel behavior. (e.g., trip duration, travel speed, trip frequency, frequently visited destinations).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I felt comfortable entering additional travel behavior and experience information (e.g., travel companionship, travel mode, activities during travel, psychological experience) using smartphone-based surveys.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would have preferred to enter travel behavior information on pencil and paper, instead of having smartphone automatically detecting such information.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I felt confident that the data collected by the smartphone would be handled in a way that protected my privacy.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Page #5 : Privacy Issues & General Concerns – Part 2**

30. Please describe your understanding of what data were collected on your phone, who will have access to the data, and how the data will be handled.

31. Please share with the researchers any general comments and/or anything interesting in your participation experience.

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Done

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