Design and Evaluation of a Mobile Snack Application for Low Socioeconomic Status Families

by

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Thesis directed by Prof. Katie A. Siek

Low socioeconomic status (SES) populations are prone to higher risks of acquiring chronic diseases including cardiovascular disease, diabetes, and hypertension. Among the major causes are individuals' everyday health-related decisions that affect their long term health, in particular their dietary and physical activities. In my research, I designed a sociotechnical intervention to improve the awareness and healthiness of snacks for a low SES population.

In this research, I employed participatory and user-centered design techniques by engaging the population through a user needs assessment, prototype evaluation, and a pilot intervention field-trial study. For the needs assessment study, I used multimedia-elicitation interviews to understand the health routines of the target population. Needs assessment findings showed that generally the population had poor dietary habits and unhealthy snacking was a major contributing factor. I also found that the target population used mobile phones that were their preferred platform for a sociotechnical dietary intervention. Based on these findings, I evaluated multiple prototype designs with twenty six caregivers to explore the usability and demographic-specific interfaces of the prototypes. I found that the parents preferred a basic, management-style design, while the teenagers wanted gaming mechanics in the application. The optimal prototype designs for each group were developed into a functional mobile phone application that was evaluated by ten low SES families during a twelve-week field trial. At the end of the field trial, the intervention group's diet was significantly healthier than the control group. The low SES families consistently used the mobile application with demographic-specific interfaces. While the parents found value in managing their family health, the teenagers were motivated by snacking game and competed enthusiastically against their parents. Both parents and teenagers mentioned that the application made them aware about their snacking, and provided useful information about healthier snacks.

While my research lays the foundation for mobile snack application design for low SES populations, it provides many future research directions such as investigation of various gaming interfaces (e.g., competition versus cooperation), theory driven application designs, considerations for multicultural community intervention design, dietary information retrieval systems, complex snack rating mechanisms, and flexible interface relevance.

Dedication

To my parents, wife, daughter, and sisters who have always loved me.

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Chapter 1

Introduction

Personal health and wellness has become a major focus in Human-Computer Interaction (HCI) community where researchers have developed different applications to empower individuals to improve their diet [35, 43, 90, 202], physical fitness [56, 131], manage chronic diseases [136, 169], and even monitor their sleep [20, 45]. With the recent advancements in ubiquitous technologies, many researchers are designing these personal health and wellness applications for mobile phones because users can carry the devices with them and access the applications wherever they want. While the majority of research is focused on mid to high socioeconomic status (SES) populations, little attention has been paid to low (SES) populations who have the highest risk of acquiring chronic diseases including cardiovascular disease (CVD), diabetes, and hypertension [1, 19, 176].

My research was motivated by a study that showed 87% of the children from a low SES population in Denver were exposed to at least one modifiable CVD risk factor [19]. The study found that poor diet and lack of physical activity were the major causes. This population was part of the Bridge Project - a community outreach program that serves over five hundred families in four Denver public housing neighborhoods. Working with the Bridge Project, we conducted interviews with the same population and found that individuals wanted to change their health habits, but did not necessarily have the financial, social, and strategic resources to support this change [135]. In a follow-up study, we found that caregivers desired family-based interventions that would improve the dietary habits of the entire family [190]. I confirmed the results from these two needs assessment studies by exploring their everyday health habits through multimedia-elicitation interviews (MEIs)

where I provided eight caregivers mobile phones for one month, and asked them to take pictures and make videos of anything that reminded them about their health. When I discussed these pictures and videos with the participants, I found that their concept of health generally centered around diet, and because of their busy schedules, unhealthy snacking was a major part of their overall poor diet. Indeed, in the last few decades, Americans have increased their snacking [179] which is a major concern for their health [94, 179]. During the MEIs, I also found that the target population had access to televisions and mobile phones and, for a sociotechnical health intervention, their preferred platform was mobile phones because they could access them virtually anywhere.

Although many nutrition monitoring applications have been developed by commercial (calorieking.com, dietpower.com), academic [60, 189, 202], and governmental sectors (ChooseMyPlate.gov), these applications did not focus on a particular aspect of diet, rather they were designed for an individual's entire diet. Furthermore, these applications did not consider the family-based context of an individual, whereas research has shown that family-based interventions are more effective than non-family-based interventions in improving an individual's health behaviors [149]. Moreover, these applications were not well informed by theory, not rigorously evaluated, and did not account for the sociotechnical and cultural needs of low SES populations.

Based on the findings of my needs assessment and given the presence of the gap in currently available dietary monitoring applications, I iteratively designed a sociotechnical intervention to improve the snacking habits of the target low SES families. To this end, I first designed and evaluated four mobile application prototypes that provided users the ability to enter snacks, receive healthier snack suggestions, and view personal and family snacking healthiness. All four prototype designs were informed by established health behavior change theories; two were non-gaming, primarily designed for the parents, while the remaining two employed gaming mechanisms to motivate teenagers towards healthy snacking. I evaluated these prototypes with twenty-six participants in a usability evaluation study where I found that, while parents wanted to manage their family health, their children were motivated and engaged by games to promote healthy behaviors.

Since parents and teenagers had different design preferences, I developed a mobile phone

application with a single back-end and two different, demographic-specific interfaces that satisfied the needs of each type of caregivers. Similar to the evaluated prototypes, the application provided individuals with the ability to capture and track their snacking information with the goal of motivating them to eat healthy snacks. The application provided just-in-time feedback of healthier snack suggestions based on the snacks entered, which was intended to encourage healthy snacking habits. The application engaged the entire family by a basic, management-style interface that was designed for parents and a gaming interface for teenagers that allowed them to compete with other family members and guide an avatar through life using points gained from eating healthy snacks.

I conducted a twelve-week field trial with ten low SES families to evaluate the mobile snacking application, and found that a mobile phone application with demographic-specific interfaces and just-in-time feedback empowered participants to be aware about their own and their family snacking habits. Contrary to many HCI field trials where the application has poor-to-moderate adoption [84, 189], my snack application was consistently used by all the users for the entire one month period. The field trial results showed that, after using the intervention, the intervention group's diet was significantly healthier than the control group, highlighting a short-term dietary behavior change. The intervention group participants also reported a greater availability of fruits in their house after using the intervention.

The users found diverse values in the application; some individuals reduced their snacking, some increased tiny meals, while some individuals added new, healthier snacks to their diet, and replaced or reduced unhealthy snacks. The parents preferred a traditional, management-style interface, whereas the teenagers in the families found the gaming interface to be engaging and fun to use. Overall, all users expressed a desire to continue using the application and engage with other community members (e.g. family, friends, and co-workers) in using the application.

1.1 Contribution

My research contributes to HCI by presenting a concrete example of how a mobile application informed by a comprehensive needs assessment, rigorous user-centered design processes, and

established health behavior change theories, can improve the healthiness of low SES families diets. This work suggests that my sociotechnical dietary intervention was able to affect the dietary awareness, self-efficacy, and social norms of the target population. These may be ideal targets for sociotechnical dietary interventions to induce a health behavior change in low SES populations.

This research also suggests the importance of engaging the entire family in the interventions we create. Throughout the studies I conducted, participants highlighted their family as the primary social-context in which they operated and one of the most important influences on their behavior. My findings suggest that improving family snacking awareness more so led to the change in behavior we found than individual snacking awareness. Behavior change in one member of the family would spread to the others, even those that were not using the application. It was clear in my study that sociotechnical interventions can have a meaningful impact on the social and environmental context in which behaviors occur, such as increasing the fruits and healthy foods available in the household. Designers should consider supporting users in changing their environment as an important strategy for applications targeted at behavior change.

Through the use of demographic-specific interfaces, my application engaged both parents and teenagers in a family-wide initiative to improve health habits. Researchers should invest the effort into designing the appropriate interfaces for different user groups when it becomes clear that a single interface will not be sufficient to meet all users needs. It is likely that the different needs of a target population will be divided along demographic boundaries, such as age and family role in our study or race and cultural background. The HCI community can increase adoption and use of mobile phone applications that require data entry by providing multiple input mechanisms that allow users to identify the ones that best meet their needs. This also helps users adapt to the shifting context of their life.

My work opens up multiple future research avenues in designing sociotechnical dietary interventions, such as exploring more formal theory driven applications and understanding considerations for multicultural community interventions. The gaming component of my application raises questions about gaming interfaces for healthy eating where researchers can evaluate how different

gaming mechanisms, such as competition and cooperation, can motivate users towards healthy eating. Finally, since it is difficult to have all the possible foods in an application database, my research encourages the evaluation of the feasibility and integration of dietary information retrieval systems that can capture and present healthiness of different foods, just-in-time on arbitrary user requests.

1.2 Research Questions

My research addresses the following questions.

- **RQ1: What are the health routines of target population?**
- **RQ2: What are the opportunities for sociotechnical interventions to provide the low SES families the ability to collect, manage, track, and share their snacking information?**
- **RQ3: How do we visualize snack consumption for the target population?**
- **RQ4: How do users engage with the application, both individually and as a family?**
- **RQ5: How effective is my application at raising awareness of their own and their family's snacking habits?**
- **RQ6: Do participants demonstrate any short-term dietary behavior change using the application?**

1.3 Road Map

I examine the motivation behind this work - how low SES populations are at a higher risk of acquiring health problems in general, and present an overview of the target population in Chapter 2. I then review the related work in Chapter 3 where I highlight what other researchers have done in the realm of dietary interventions, and the work that has been done in this regard for low SES

populations. Chapter 4 presents previous work including interviews, workshops, and a focus group conducted with the target population as an initial phase of needs assessment. I also provide my proposed approach to address my research questions. In Chapter 5, I address RQ1 and RQ2 where I discuss multimedia-elicitation interviews, and justify why I selected to develop a family-based mobile application to improve target population's snacking. Chapter 6 addresses RQ3 where I describe four mobile phone-based snack application prototypes, and present a usability evaluation of these prototypes with the target population. Finally, I answer RQ4, RQ5, and RQ6 in Chapter 7 where I discuss the application deployment and the results of the twelve-week field trial.

Chapter 2

Background and Motivation

My primary motivation for this research was to improve health of low SES populations by designing a sociotechnical intervention. While the affluent have access to numerous facilities and resources, people with low SES have to cope with low income and limited education. Research shows that individuals with lowest income are consistently least healthy [26]. Moreover, not only socioeconomic disparities in the US are increasing [184] but also the underserved populations have limited access to healthcare as compared to their higher SES counterparts [5]. Although the low SES populations have access to food supplements and nutrition education programs such as Women, Infants, and Children (www.fns.usda.gov/wic/), more efforts are required to assist this population with their everyday health management.

2.1 Target Population

The target population for my research was recruited from the Bridge Project - a community outreach program that serves over five hundred families in four Denver public housing neighborhoods. Most of these families are from diverse ethnic groups and live below the poverty line. The Bridge Project offers educational programs including after-school, summer, and scholarship programs to primary school, high school, and middle school students for their K-12 curriculums. To keep a strong trusting relationship with the Bridge Community, I have volunteered as a tutor for middle school and high school students for more than fifty hours. The specific locations where I conducted this research include the Bridge Project sites located at South Lincoln, Columbine, and

Westwood.

I selected this specific population because a study conducted by University of Colorado Denver, School of Nursing showed that 87% of children in the Bridge Project were already exposed to at least one modifiable CVD risk factor [19] by preschool age. The leading factors were poor diet and lack of physical activity. Informed by these findings, my research lab started Project HealthBridge where they further explored target population's barriers to healthy dietary behavior. The details of this previous work are presented in chapter 4.

2.2 Technology Access and Narrowing Digital Divide

Since the low SES populations have limited access to healthcare resources [5], the family caregivers play an important role of caring for their family's health. Given that the target population has access to mobile phones and televisions, research is needed to explore technologies that assist the underserved caregivers to effectively manage the health of their family. The recent advancements in personal health and wellness mobile applications have the potential to translate into effective tools that empower individuals in managing their health information and sharing it with trusted parties.

I was further motivated to conduct this research because the increasing ubiquitous nature of technology is narrowing the digital divide [27] and providing researchers opportunities to design technologies that assist low SES populations in managing their health. In particular, preventative applications can be designed for the Information Communication Technologies (ICT) that provide just-in-time feedback to promote health in the low SES populations. To this end, one area where technology can help underserved populations is to improve their awareness about healthy eating since unhealthy diet is a major cause of their poor health [188]. Thus, my research is focused on improving the dietary habits of a low SES population using technology already available to them.

Chapter 3

Related Work

The concept of designing an application that engages low SES families through managing and sharing their snacking information requires the review of a broad range of literature. I would first acknowledge that there have been numerous non-technological dietary interventions [38, 66, 69, 92, 205, 214] that used group counseling [69], personalized booklets [38], mail-in newsletters [205], class-based intervention methods [92], and telephone calls and brochures [66, 214]. However, these interventions generally require an ongoing active involvement of nutritionists or dietary experts, they are more costly to conduct, and they are not pervasively available such as mobile phone-based interventions. Moreover, studies have shown that a face-to-face dissemination is not more effective than an online dissemination for dietary intervention [100].

Therefore, for this literature review, I primarily focus on technological interventions to improve dietary habits. This section begins with a discussion on technological interventions to improve individuals' dietary habits. I further examine different researchers' efforts to design health-related technologies for low SES populations. Since my work also employs persuasive gaming techniques, it is important to review how gaming applications motivate people to improve their dietary behaviors. Furthermore, I highlight how involvement of families affect the motivation to use health intervention. I also briefly discuss automatic dietary assessment applications that utilize camera phones and image recognition to identify and record food intake. Finally, I discuss different behavioral change theories that researchers have used for designing health intervention technologies.

3.0.1 Technological Interventions to Improve Dietary Behavior

Diet has a significant impact on an individual's health, and aptly, researchers have designed and evaluated numerous technological interventions to improve individuals' dietary habits. Recent intervention studies have been successful in improving individuals' dietary behaviors [8, 24, 101]. Some of these interventions include mobile phone applications, interactive multimedia websites, kiosk-based interventions, and email and text-messaging-based interventions. Although there have been health interventions where researchers studied diet and physical activity of individuals, I will focus on the interventions that addressed only the dietary behaviors. A summary of these interventions is presented in Table 3.1.

3.0.1.1 Mobile Phone Nutrition Applications

The recent surge in consumer health technology has given rise to many innovative nutrition applications for mobile phones. The most popular mobile Android dietary applications target calorie count; these include Calorie Counter - MyFitnessPal [147], Calorie Counter by FatSecret [32], and Calorie Counter by caloriecount.com [31]. Among the dietary monitoring applications from the academic sector, Denning et al. [60] developed BALANCE - a mobile phone based application for long term wellness management with food entry and caloric expenditure measurement capabilities. Apart from a mobile phone, the BALANCE system required a wearable component to track an individual's movements for estimating the caloric expenditure. Similarly Tsai et al. [202] developed a mobile phone application to monitor real time caloric balance. However, these applications attempted to estimate the exact caloric intake - something that our target population is not interested in monitoring.

For snacking, the commercially available mobile phone applications generally focus on healthy snack recipes such as Free Healthy Snack Ideas [33] and Healthy Snacks [34]. These applications however do not provide the ability to track snacking. Moreover, all of the aforementioned technologies did not take into consideration the social, cultural, and economic needs of low SES populations.

Table 3.1: Technological interventions to improve dietary habits

Studies	**Platform**	**Intervention Type**	**Theoretical Framework**	**Motivational Strategies**	**Population**	**Outcome**
Anderson et al. [8]	Kiosk	Supermarket kiosk	SCT[1]	goal setting, personal monitoring, feedback	N=277; I=129; C=148	Decrease in fat, increase in fiber, fruits and vegetables
Irvine et al. [101]	PC	Interactive multimedia website	SCT, TTM[2], TRA[3]	goal setting	N=517; I=260; C=257	Decrease in fats, increase in fruits and vegetables
Oenema et al. [155]			PAPM[5]	feedback, goal setting	N=616; I=188; C=428	Increase in vegetables intake, no effect on fruit and fat intake
Long et al. [132]			SCT, TTM, Education	feedback	N=121; I=63; C=58	No effect on fruits, vegetables, and fat intake
Block et al. [24]		Automated emails	PAPM, TTM	goal setting, social support	N=47; I=47; C=0	Decrease in fat and increase in fruits and vegetables
Tsai et al. [202]	Mobile Phone	Application	EMA[4]	goal setting, caloric intake monitoring	N=15; I=10; C=5	Change in eating behaviors
Ahtinen et al. [6]			CBT[6]	self monitoring	N=11; I=11; C=0	-
Gerber et al. [79]		Text messaging	Educational	-	N=95; I=95; C=0	Assistance towards weight loss goals

[1] Social Cognitive Theory; [2] Transtheoretical Model; [3] Theory of Reasoned Action; [4] Ecological Momentary Assessment; [5] Precaution Adoption Process Model; [6] Cognitive Behavioral Therapy
; I=Intervenion; C=Control

While these technologies work well for the general population, our target population lacks general nutritional knowledge of their diet (e.g., calories, carbohydrates, vitamins, etc).

3.0.1.2 Interactive Multimedia Websites and Applications

Researchers have developed many interactive multimedia applications and websites to promote healthy eating behaviors. For example, Haerens et al. [93] designed a fifty-minute computer-tailored dietary fat intake intervention for adolescents, and evaluated it with seventh graders from ten different schools. They found a decrease in dietary fat consumption in some girls from the intervention group, however no intervention effects were detected for the total sample. The results also showed that half of the students thought that the intervention message was too long, and one fourth did not even read the message.

Irvine et al. [101] designed an interactive multimedia program to improve the diet of employees. The program was hosted at two different worksites and provided users healthy eating strategies, cooking recipes, eating habits assessment, and quick tips. The results showed an increase in fruits and vegetables intake, and decrease in fat in participants' diet. Although repeated use of the program was encouraged, the study showed that less than 15% of the participants used the program second time and less than 8% used it for the third time. In another study, Oenema et al. [155] designed an interactive multimedia website for 18 - 65 years old individuals to decrease saturated fat and increase fruits and vegetables in their diet. The researchers found that the intervention increased fruits and vegetables intake in participants' diets but did not have any effect on their fat intake. Similarly, Thompson et al. [200] designed a nutrition goal-driven website and evaluated it with eighty eight-to-ten year old African American girls who used it for eight-week in a home-based program. Results showed statistically significant pre-to-post differences in fruit, juice, and vegetable consumption.

Although some technological interventions succeeded in improving individuals' dietary habits, others had limited effect because they only improved individuals' knowledge about healthy eating. For example, Long et al. [132] designed a nutrition education website for students in 7th - 9th

grade. The website used three modules to provide a five-hour long nutrition education course to the students. The researchers also designed a ten-hour in-class course complementary to the website. Although the students who used the intervention showed an increase in nutrition knowledge, there was no change in the eating habits of the intervention group as compared to the control group. Therefore, simply educating people about healthy eating is not enough, rather we need to design a technological intervention that engages them to actually change their dietary behaviors in their everyday lives.

3.0.1.3 Nutrition Monitoring Desktop Applications

With the advancements in mobile and cloud technology, in the last few years, we have witnessed a major drop in desktop-based standalone applications. However, there are still plenty of commercially available desktop software including DietMaster 2100 (dietmastersoftware.com), Nutrinote (nutrinote.com), and DietPower (dietpower.com) that provide users the ability to track dietary and physical activity information e.g., nutrient history, body measurements, and meal plans. Since desktop computers are not the preferred intervention platform for the target population, these applications are of limited use for them.

3.0.1.4 Email and Text Messaging Based Interventions

Apart from designing interactive multimedia applications, researchers have also used emails [24, 216] and text-messages [79] as a medium to administer interventions to improve individuals' dietary behaviors. However, these types of interventions sometimes suffer from a lack of response from the participants. For example, Woodall et al. [216] conducted a four-month study with 380 participants in the intervention group where participants received four email alerts five weeks apart that encouraged healthy eating. Only 23.5% of the participants responded to at least one email by clicking a website URL. Block et al. [24] conducted a twelve-week study, in which the participants received weekly emails tailored to their dietary lifestyles to improve their eating habits. Results showed that the participants reduced fats and increased fruits and vegetables due to the

intervention.

3.0.1.5 Supermarket Interventions

Most of the individuals in the United States buy their food supplies from supermarkets. Therefore, supermarkets provide an interesting opportunity for inducing dietary behavior change in their shoppers. Therefore, researchers have designed technological interventions [8, 142, 212] in cooperation with supermarkets to improve their shoppers' health habits. For example, the Nutrition for a Lifetime System© [212] (NLS) - a multimedia, public-access system that is installed on kiosks in supermarkets and provides individuals nutritional guidelines to improve their diet. Anderson et al. [8] conducted a study with the NLS system and found that participants in the treatment group decreased their fat intake and increased fiber, fruits, and vegetable intake as compared to the control group. The NLS system also provided the participants with coupons to encourage them to buy healthy food items. Similarly, Mhurchu et al. [142] recruited 97 individuals for a twelve-week long supermarket intervention study and found that electronic shopping data provided researchers an opportunity to examine the dietary trends of people. The study also showed that despite offering coupons on healthy food items, there was a low participation by minorities and low-income individuals. Although supermarkets provide an interesting venue for health intervention studies, research has shown that the effectiveness of supermarkets is limited as compared to other environments [186].

3.0.2 Health-related Technologies for Low SES Populations

The technologies developed specifically for low SES populations to manage their health have been limited to healthy eating websites [201], interactive multimedia teaching applications [37, 104], CD-ROM mediated intervention content [62], and nutrition-related memory sharing programs [84]. Noia et al. [62] designed transtheoretical model-based CD-ROM-mediated intervention content that was provided to low SES youths in four thirty-minute sessions. They found that youths using the intervention reported higher consumption of fruit and vegetables. Grimes et al. [84] developed

EatWell - a mobile phone-based application for a low-income African American community that provided users the ability to create and share voice memories explaining how they ate healthfully. The researchers conducted a four-week study with 12 participants and found that the participants shared culturally-relevant stories that built a sense of community empowerment among them. The participants created 38 nutrition-related memories; less than one nutrition-related memory per participant per week. In another work, Rilla et al. [109] designed a persuasive smoking cessation game for New Zealand European and Māori users that highlighted the importance of culturally-relevant applications. Similarly, the proposed intervention will be designed considering the cultural, social, and economic needs of the target population. To our knowledge, there is no technological intervention specifically designed for low SES families that provides them the ability to capture, manage, and share their snacking information to improve their snacking behaviors.

Block et al. [23] designed *Little by Little* - a standalone program developed to increase fruits and vegetables intake, and reduce fat intake in low-income populations. The program offered users two modules: (1) dietary fat intake; and (2) fruits and vegetables intake. The program asked users screening questions, and provided them tailored feedback and goal setting functionality. The researchers evaluated *Little by Little* by conducting a study, in which 481 low-income participants aged between 45 - 60 years old were placed either in a control group or intervention groups [25]. Participants in intervention groups used the fruits and vegetables module of *Little by Little* for approximately 15 - 20 minutes. The researchers conducted a two-month follow-up assessment and found that the participants in the intervention group had increased fruits and vegetables intake as compared to the control group. This research showcased an excellent example of how a technological intervention can improve dietary habits of low SES populations. However, *Little by Little* was designed for desktop computers which are not readily available to the target low SES families.

3.0.3 Games for Improving Dietary Behavior

Research has shown that games can not only be used as an effective learning tool [57, 177], but can also be used to encourage people towards healthy eating behaviors [16, 90]. The *Let's Move!*

(www.letsmove.gov) campaign initiated by the First Lady of the United States, Michelle Obama, to fight against childhood obesity, has promoted health-related games by offering prizes (www.appsforhealthykids.com) for innovative, fun, and engaging software. Most of the games developed for the *Let's Move!* campaign are gaming websites that are designed for desktop computers, which the target low SES families generally do not own. Apart from this initiative, several games have been designed and evaluated by researchers. For example, Baranowski et al. [16] designed a multimedia game for fourth-grade students to increase fruit, juice, and vegetable (FJV) consumption in their diet, and found that children who played the game increased their FJV intake by 1.0 serving over children who did not play it. The game, however required at least 25 minutes to complete a single session, which is not feasible for the target low SES families since they did not want to spend more than five to ten minutes per day on any technological intervention.

Grimes et al. [85, 90] developed *Order UP!*, a game in which the player assumed the role of a restaurant server who had to quickly make healthy meal recommendations for the restaurant customers. The player was provided feedback based on the healthiness of the food that she recommended for the customers. Initially, all the customers had some health value that decreased over time based on how unhealthy the food was that the server recommended to the player. Once the health value went below a pre-defined threshold, the player would lose her job and the game ended. The designers made a decision to always reduce the health value of customers which implied that generally, eating outside of the home was unhealthy. The game was initially designed for low-income African American communities [85], however it was evaluated with a higher SES participants [90]. The researchers conducted a three-week study, in which Nokia N95 mobile-phones with *Order UP!* were provided to twelve participants. The findings revealed that most of the participants learned eating healthfully after playing the game, however they wanted detailed feedback rather than the simple stop-light metaphor. This exhibits the value of feedback in a dietary application. For my research, I will explore various feedback issues in prototyping to make sure that participants receive optimal feedback from the application.

The introduction of the field of persuasive technology [74] has led researchers to explore

persuasive games that can improve individuals' dietary behaviors [44, 167]. For example, Chiu et al. [44] designed *Playful Bottle*, a game-based system to promote healthy water intake. The system consisted of a mobile phone that was attached to a drinking bottle through LEGO bricks. The researchers provided Playful Bottle to sixteen office workers and found that computer-mediated social persuasion resulted in a higher water intake in the participants as compared to computer-automated persuasion alone. Although this intervention was evaluated in an office environment, the fact that social persuasion was more effective than non-social intervention motivates me to have a strong social element in my application.

Other persuasive games have been designed on the concept of a virtual-pet care after the tremendous success of the commercial products including Tamagotchi and Nintendogs. Pollak et al. [167] designed *Time to Eat*, a mobile phone-based, virtual-pet care game to encourage healthy eating habits in children. The researchers conducted a month-long study in which mobile-phones with *Time to Eat* were provided to 53 seventh and eighth graders. They found that children playing *Time to Eat* ate healthy breakfasts more frequently as compared to those children who did not play the game. Given these benefits, the researchers acknowledged an area for possible improvement: players of *Time to Eat* did not receive an instant feedback after sending their food pictures to the researchers since the emotional state of the virtual-pet was only updated after the researchers had identified and rated the healthiness of the food. This lag can cause a disconnect between the player's eating behaviors and the virtual-pet's emotional state. Therefore, it is important to provide the player an instantaneous feedback once she enters her food information into the application. Although research has shown that family-based interventions are more effective than non-family-based interventions [149], these games [90, 44, 167] did not consider the family-based context.

3.0.4 The Role of Family in Health Interventions

The role of a family cannot be underestimated when designing technological interventions to improve health behaviors. Researchers have examined and recognized the positive influence that

family has on an individual's health. Research showed that family-based meals resulted in better health [68, 80, 196]. Elsie Taveras et al. [196] showed that the frequency of eating dinner with family was inversely related with overweight prevalence in children. Similarly, Matthew Gillman et al. [80] found that family-based dinners resulted in a healthy diet including more fruits and vegetables, less fried food and soda, and less saturated and trans fat. In sight of these benefits, researchers have explored how technology can leverage the family-based context to improve individuals' health [49, 50, 91]. Colineau et al. [49] designed a web-based health portal for families to study how they could be motivated to reflect on their lifestyles to improve their health. The study found that families, more motivated as a whole when they were assigned a collective goal along with appropriate feedback. My work is inspired by these findings to promote and maintain best health behaviors for the low SES families.

3.0.5 Automatic Dietary Assessment

While most of the interventions discussed earlier rely on the user to enter food name and portion size, lately researchers have been working on automatic dietary assessment applications that utilize image recognition techniques to identify food type and portion size. A recent example is DietCam [116] that recognizes food and calculates calorie content in a meal from images or videos. Although the food recognition accuracy varies with the number of food items in a plate and external factors (e.g., lighting), a major barrier to its success is the extended user input burden due to camera calibration requirements. For example, DietCam requires users to place a credit card next to a meal plate, and take three pictures 120 ° apart or make a video. Similarly, Woo et al. [215] require users to place a fiducial checkerboard marker in every meal image for subject size estimations. Finally, Zhu et al. [217] provide multiple alternatives for camera calibration: place a pre-calibrated object next to meal plate, or have the meal plate itself pre-calibrated, or place a table cloth with checkmarks of known size. Unless the end-user burden is reduced, automatic dietary assessment cannot be practically used for a real-world field trial.

Chapter 4

Previous Work

My research builds on previous work where we investigated the target population's perceptions about health [135] and what kind of technological solutions they desired [190].

4.1 Focus Group and Interviews

In [135], we reported findings from one-to-one interviews with fourteen primary caregivers and a focus group of three primary caregivers where we discussed topics of health, diet, and technology. We found that the emergent themes generally centered around lack of time, financial pressures, and the need for developmental knowledge to support the desire to change.

4.1.1 Forced Precontemplation

We applied the Transtheoretical Model of Behavioral Change (TTM) [170] and observed that different participants were in different stages of dietary behavioral change. Many participants were in the precontemplation stage of TTM due to lack of resources rather than motivation. Thus, we added another stage to TTM that we called *"Forced Precontemplation."* Although the individuals had a general knowledge about healthy food, they struggled to convert this knowledge into their everyday healthy diet. The participants were not sure about how and where to start healthy dietary change.

4.1.2 Unabsorbable Information

The participants cited family doctors as being trusted source of information, however the information they provided was of limited use because it included medical guidelines and terminologies that the participants found difficult to understand. They also mentioned that a cultural and contextual disconnect between the message given by health care providers and the recipients further contributed as a barrier to usable information. While some participants used the Internet to search for healthy recipes, most of them perceived it as too complex for searching specific health-related information.

4.1.3 Taste-based Food Choices

We also found that the primary caregivers did not want to waste food and only bought food that their children preferred. Most of the primary caregivers mentioned how their children did not eat healthy food and it would often rot. The primary caregivers did not try new, healthier recipes because of their concerns with wasting food. Another reason for not buying good quality, fresh produce was the limited availability in their area. The cheaper markets near their locality carried low quality fresh produce while the shops that carried good quality food were too expensive.

4.1.4 Barriers to Common Health Solutions

During the interviews, we discussed common methods that could be used to promote healthy eating. One such method is meal planning because it allows for a variety of healthier, well-balanced meals for less money. However the primary caregivers cited time constraints, lack of space, and financial uncertainty as major barriers to meal planning.

Another approach towards healthier dietary choices is to have discussions and exchange of ideas within their families and friends about how to eat healthy. But we found that although most of the families faced similar health-related hardships, generally, they did not discuss healthy living, and in some cases health-related conversations were even considered taboo.

4.2 Participatory Design Workshops

In another paper [190], we presented results from two participatory design workshops with nine caregivers and thirteen children from low SES families where we investigated what they wanted in health promoting technological interventions.

In the design workshops, we had separate groups of caregivers and children who were asked to perform different activities where we sought to understand their thoughts on diet and exercise through brainstorming, insight, and design exercises. The specific activities included a word association task, scenario-building through storyboards, and creating an augmented object.

4.2.1 Word Association Exercise

During the word association exercise, we found that fats and sweets contributed as the largest percentage of food words listed by caregivers when thinking about family diet. The caregivers cited fast food as being a quick dinner and time fix in their busy schedules. In general, health-related words, depression and mental health words repeated most frequently.

4.2.2 Augmented Objects Exercise

In the augmented object exercise, we gave them four pre-made objects including a cell phone, a computer, a video game system, and a blank 3D cube that they could augment. In addition, we also provided them a blank paper. The participants sketched different augmented devices on a paper which highlighted that they wanted reminder-based systems that could help them to manage their health and care for their family members. Examples of reminders included drinking water, avoiding fast food, and doing more exercise. Other augmented objects provided the functionality of logging and tracking nutritional and exercise data.

4.3 Discussion: The Role of Technology

We realized that there were some major obstacles before technology could have played an integral role in changing the target population's health behaviors. However, Barton et al. [19] reported poor health status of target population highlighted that current approaches were not working. Given the interviews and design workshop findings, we identified that there was some space for technology that could help the target population in improving their dietary habits, albeit there was no silver bullet. We suggested that systems should be designed that do not pursue a complete change of dietary intake, rather they should assist users in setting realistic and incremental goals. These systems should provide concrete, implementable steps towards achieving the health goals. We also suggested that the HCI community should design systems that facilitate exchange of health messages but localize the design according to cultural and socioeconomic context.

4.4 Proposed Approach

Building on our previous work, I broke down my research into three studies that utilized participatory and user-centered design techniques to engage the participants to explore the snacking issues and design appropriate sociotechnical intervention. The studies were generally exploratory, however, there were some confirmatory activities to verify previous findings.

4.4.1 Multimedia-Elicitation Interviews

The first study was the final phase of the user needs assessment that was designed to understand the target population's everyday health routines. I provided mobile phones to eight caregivers from the target low SES population and asked them to take pictures for one month of anything that reminded them about their health. I also included some low-fidelity prototyping exercises to understand how they interpreted the current standard-health management interfaces. In these multimedia-elicitation interviews (MEIs), I found that the target low SES families had busy schedules that resulted in quick, unhealthy snacking which in turn contributed to their overall poor diet.

From a technology standpoint, I found that they had access to televisions and mobile phones, but they mentioned that mobile phones were their preferred platform for a sociotechnical intervention. Chapter 5 presents details about the MEI study.

4.4.2 Prototype Evaluation

Based on the MEI findings, I designed two gaming and two non-gaming mobile phone prototype applications to manage and share snacking habits. I evaluated these prototypes in a usability evaluation study with eight primary caregivers and eighteen secondary caregivers. I found that the primary caregivers wanted a basic, snack-management interface while the secondary caregivers preferred gaming designs. The prototype evaluation study is presented in detail in Chapter 6.

4.4.3 Field Trial

I developed a functional prototype mobile phone application, Snack Buddy, informed by the prototype evaluation results. Snack Buddy had demographic-specific interfaces supported by the same back-end and provided users with the ability to track and share their family snacking. I evaluated the application in a twelve-week field trial with ten participants from five low SES families in the intervention group and ten participants in the control group. I found that the intervention group participant's diet was significantly healthier than the control group after the twelve-week duration of the study. The participants mentioned that the application made them aware about their snacking habits and made their snacking healthier. Details of field trial are presented in Chapter 7.

Chapter 5

Multimedia Elicitation Interviews

The objective of this study was to explore the target population's health routines and to confirm the findings from our previous studies. This study answers: RQ1 by multimedia-elicitation interviews that indicate that the target population has poor dietary habits and unhealthy snacking are a major contributor; and RQ2 by design exercises and semi-structured interviews that show the target population has access to mobile phones and televisions, but due to their pervasiveness, they prefer mobile phones as a platform for a sociotechnical health intervention.

This study was the final phase of a broader user needs assessment in which my research lab had earlier conducted interviews [135] and family-based design workshops [190] to explore what the target population said about personal health [135], and what kind of health solutions they desired [190]. The Multimedia-Elicitation Interview (MEI) study informed us about their actual health habits and practices. The study was designed to help me identify specific areas of concern where a sociotechnical intervention could help in improving the health habits of the target families. I published the findings from this study in: [110] that was focused on understanding the target population's everyday health routines; and [113] where I presented the design exercises and semi-structured interview results. The novel part of this study reported here include the MEI usage statistics presented in Table 5.1, and the details presented in sections 5.5.4, 5.5.5, 5.5.6, 5.5.7, and 5.5.8. The discussion section 5.6.4 on health management applications is also novel and was not published earlier. Finally, this is the first time I am reporting the MEI study in its entirety whereas in the previous two publications, I reported specific parts of the study.

5.1 Study Objectives

The specific objectives of the MEI study were as follows:

(1) Explore the target population's everyday health routines;

(2) Understand what health metrics low SES caregivers want to track for themselves and their families;

(3) Discover what technological platforms the target population finds useful;

(4) Explore visualizations of both single and multiple health data streams.

5.2 Participants

After receiving approval from the Institutional Review Board (IRB), I worked with the Bridge personnel to recruit the participants. The Bridge personnel informed me that generally in the low SES families, there is a primary caregiver (mother) and a secondary caregiver - teen sibling who cooks food and provides care to her/his younger siblings. Therefore, I recruited eight participants in total - four primary caregivers and four secondary caregivers. The recruitment was facilitated by the Bridge personnel who identified the potential candidates for the study. Initially, I recruited eleven participants, however, two participants, who were primary caregivers, dropped from the study due to schedule conflicts while another participant left the study for personal reasons.

5.3 Methods

For this study, I used MEIs to explore the target population's current health habits. In the MEI method, participants are provided with devices (e.g., mobile phones) that can record videos and take pictures. The researcher meets with the participants regularly to discuss the multimedia content that they captured. I was motivated to use this method because social scientists [28, 46, 47, 126, 159] have successfully used a similar method: Photo-Elicitation Interviews (PEIs) to learn about individuals' daily life routines. In PEIs, participants only take pictures from their

everyday life, however, I wanted to capture broader contextual information (e.g., background sounds and settings) and therefore used the MEI method. Elsewhere, the MEI method was used by Vincent O'Brien and fellow researchers [154] to explore everyday health experiences of individuals living in Kyrgyzstan and Brazil.

I met with the participants individually, five times in total. A summary of the meetings is provided below:

- Meeting 1: In the first meeting, I briefed the participants about the study and provided them a camera phone (Nokia N95 8gb) with its charger and demonstrated: (1) How to make videos using the mobile phone; (2) how to charge the mobile phone; and (3) how to turn on the phone. The participants were asked to make videos and take pictures of anything that reminded them of health and provided examples of eating, exercising, and grocery shopping. Printed instructions were also provided to the participants describing how to use the mobile phone.

After the first meeting, I met the participants weekly for one month to conduct interviews about the videos and pictures the camera phones. I started these meetings by first transferring the multimedia objects from the camera phones to my tablet PC, I then conducted semi-structured interviews that were video recorded with participants' consent for later analysis. The interviews and exercises of Study 1 were based on the participatory design approach [102, 105] because research has shown that useful feedback can be obtained when caregivers are treated as knowledge experts with equal importance [105].

- Meeting 2: The second meeting was exploratory where participants discussed their everyday health routines.

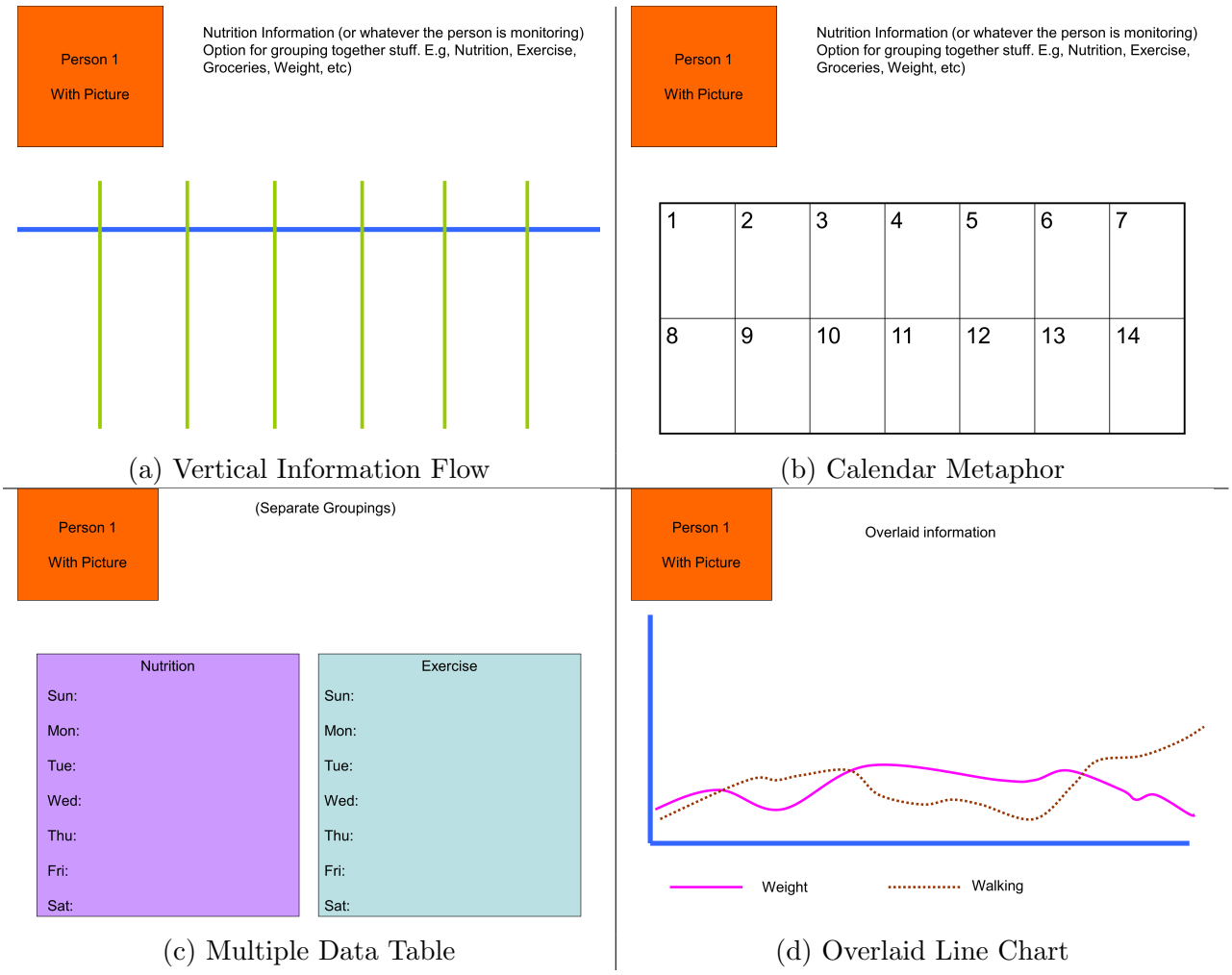
- Meeting 3: While the second meeting focused on the first study objective, in the third meeting I conducted a semi-structured interview where I addressed the second and third study objectives. Towards answering the second objective, I initially explored whether

the participants wanted to monitor their health and the reasons for monitoring it. I then investigated what specific metrics they wanted to track for themselves and their family. To address the third objective, I identified what technological platforms were readily accessible to the target population and which of these platforms they preferred for a health monitoring application. I explored why specific platforms were more appealing and conducive for use than others. As part of this objective I also asked the participants how often and how long they would use a potential health monitoring application. A related goal here was also to understand at what granularity participants were comfortable with capturing and viewing data.

- Meeting 4:

  In the fourth meeting, I explored the final objective of visualizing health data streams. Particularly, Meeting 4 focused on visualizing a single health data stream (e.g., the health data generated by one person) through prototyping activities. Thus, I presented them with six prototype interfaces on a touchscreen tablet PC (Lenovo X60) that visualized health data of a relatable persona. As the participants viewed the prototype interfaces, they were asked about which prototype they preferred and why they preferred it. After I discussed the prototype interfaces, participants were asked to draw a prototype on the tablet PC that visualized their preferred health metric.

  All the prototype interfaces, shown in Figure 5.1 were borrowed from PHAs available in 2009 that generally visualized health data in a table-form or line charts with respect to time. The vertical information flow prototype (Figure 5.1a) was designed to understand vertical versus horizontal information flow. The participants were provided sample information within the vertical lines according to their preferred health metric. For example, if the participant wanted to manage diet, then an itemized list of food items was provided below the horizontal line while the time span (e.g., day, week, etc) was provided on top of it. The participants were also shown a horizontal version of Figure 5.1a. Apart from entering



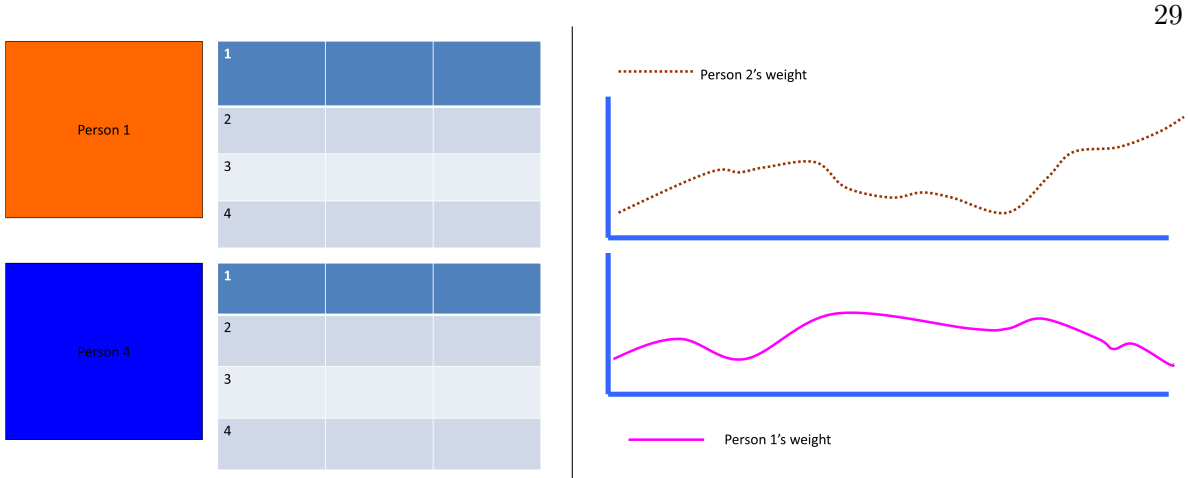
(a) Vertical Information Flow

(b) Calendar Metaphor

(c) Multiple Data Table

(d) Overlaid Line Chart

Figure 5.1: Meeting 4 Prototypes for Visualizing a Single Health Data Stream



(a) Multiple Data Streams

(b) Longitudinal Weight

Figure 5.2: Meeting 5 Prototypes

and viewing textual information, the participants were told that pictorial representations of health metrics were also possible and were asked about their preference between text and pictures. The calendar metaphor prototype (Figure 5.1b) was designed to explore whether participants wanted the standard calendar as an interface for managing their health information. The participants were told that they could click the calendar boxes and enter information about their health. I also examined whether the participants preferred information in separate groupings or in an overlaid form. For example, Figure 5.1c shows a multiple data table prototype where different boxes contained information about different health metrics. For overlaid information, I designed a line chart prototype that visualized weight and walking activity with respect to time in Figure 5.1d.

- Meeting 5:

  The final meeting also addressed the fourth objective and focused on visualizing multiple health data streams. Similar to the previous meeting, the final meeting also consisted of prototyping activities where seven prototype interfaces were discussed that focused on visualizing an individual's family health and therefore displayed multiple health data streams. Figure 5.2 shows the prototypes designed for Meeting 5. The multiple data streams pro-

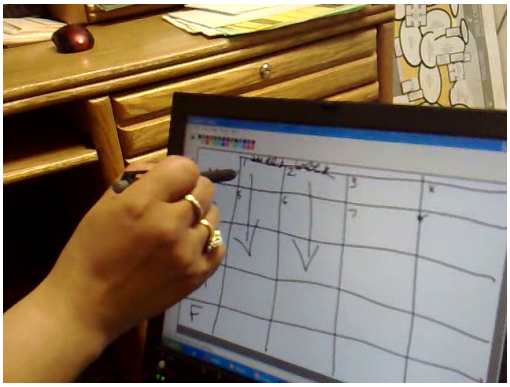


Figure 5.3: Participant drawing a prototype on a tablet PC

totype (Figure 5.2a) visualized health information of different family members in different data tables. This prototype had two variations with side-by-side and top-bottom placement of data tables. I also asked participants whether they preferred fixed or independent time scales for multiple data streams. The comparative information prototype (Figure 5.2b) was designed to track and compare two individual's weight. The participants were told that the line graph did not necessarily show an individual's actual weight, but could also be only change in weight. I also used a prototype similar to Figure 5.2d, where the weight of two individuals was overlaid for comparison. At the end of Meeting 5, as shown in Figure 5.3, participants were asked to draw a prototype on the tablet PC that visualized their preferred health metrics for their family's health.

For the entire MEI study, participants were given a $30 incentive in the form of supermarket or retail store gift cards. The incentive was prorated $5 each for the second and third meetings and $10 each for the last two meetings.

5.4 Analysis

The interview videos and the videos captured by the participants were transcribed and coded using NVivo 8 Qualitative Data Analysis Software. I used the grounded theory principles [4] to find the emergent themes, which were discussed with fellow researchers to draw out key findings.

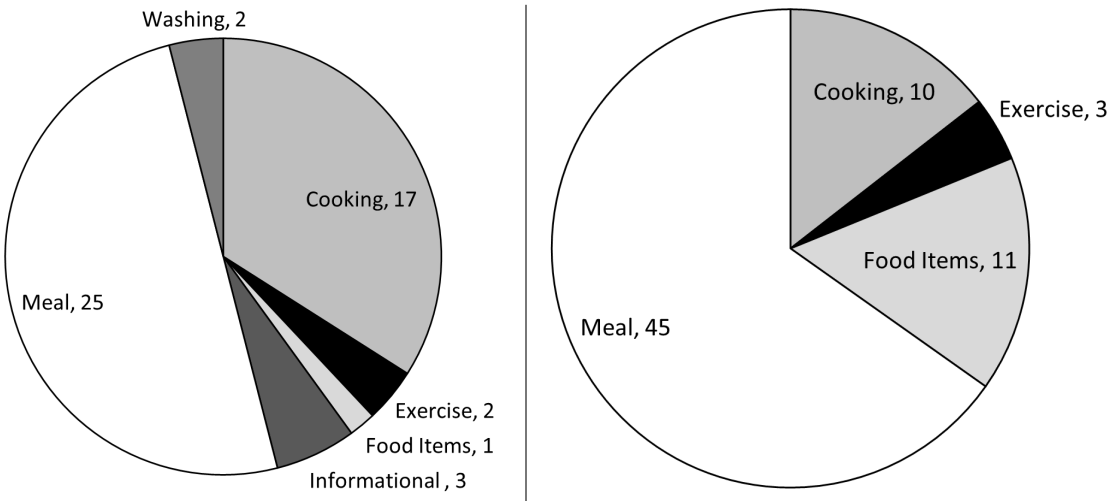
5.5 Results

The eight participants captured a total of 63 videos and 56 pictures of everyday items that reminded them of health. I found that the target population's perceptions about health predominantly related to their diet since most of the multimedia content was about food, especially meals and cooking. Unhealthy snacking habits contributed to the poor diet of the low SES families. One participant snacked after her kids went to bed because she did not want to pass on the bad habits to them. Another participant referred to pizza as a snack and mentioned that her children snacked on it quite often. One particularly interesting finding revealed that a recently immigrated Somali family had a healthy diet despite their low SES context, however another Somali family started eating pizza regularly even though pizza was not their native food. This demonstrated how the geographically surrounding culture affected the families' native culture, similar to a finding reported elsewhere [30].

I also found that culture and family-based practices were deeply ingrained in various health related activities of the participants. Individuals generally acquired cooking and dietary knowledge from their families. This created opportunities for family-based interventions where the entire family participates in using the sociotechnical intervention to improve their snacking habits. Confirming our previous findings, the participants had a general idea about good food, but had limited knowledge about nutrition. The study also revealed that the participants were not interested in monitoring the nutritional components of their diet (e.g., proteins, vitamins, etc). The participants mentioned that mobile phones would be the most appropriate technology because they were portable and everyone owned a phone. The participants were willing to spend five to ten minutes everyday using the sociotechnical intervention to improve their health habits.

5.5.1 Usage Patterns

I collected a total of 119 multimedia objects (videos and pictures) and computed separate usage statistics for primary and secondary caregivers. The videos and pictures were then analyzed to



(a) Primary Caregivers (Mothers), N=50 (b) Secondary Caregivers (Teenagers), N=69

Figure 5.4: Multimedia objects breakdown

identify major themes and examined how they affected the understanding of diet in the caregivers' lives.

The majority of the content of their activities, as shown in Figure 5.4, consisted of meals and cooking. While there were a few pictures and videos of exercise, caregivers primarily equated health with diet. Most of the meals captured were dinners. The mothers captured more cooking related activities compared to the teens, confirming their role as primary caregivers. The food items in Figure 5.4b represent multimedia objects that consisted of food stored in the home.

As seen in Figure 5.4, there were few instances where participants made videos of exercising. These videos were discussed during the MEIs, and it was found that most of the mothers only reported walking. The African American teenagers exercised regularly and participated in directed sports including basketball and track. The Somalian teenagers documented walking and occasional jogging. In the rest of the findings, I focus on diet because 86% of mothers' and 96% of teenagers' videos/pictures were about their diet.

Table 5.1 presents an overview of usage statistics by the caregivers. While teenagers used pictures as the communication medium, mothers primarily used video. This can be attributed to two reasons - (1) teenagers did not want to make videos in their schools and (2) Somalian

Table 5.1: Usage Statistics

Caregiver	Content	Total #	Total Length	Avg. #	Avg. Length/ Video	Usage/ week
Mothers	Videos	44	54.6 min	11 (s.d.= 9.6)	1.2 (s.d.= 1.7) min	2.3
	Pictures	6	n.a.	-	n.a.	
Teenagers	Videos	19	41.7 min	4.8 (s.d.= 3.2)	2.2 (s.d.= 3.4) min	2.9
	Pictures	50	n.a.	12.5 (s.d.= 9)	n.a.	
Total	119	96.3 min				

teenagers did not feel comfortable making videos, thus they took more pictures. The mothers averaged 11 videos (s.d.= 9.6). The high standard deviation is because one mother took 25 of the 44 videos. Similarly, the standard deviation for pictures taken by teenagers is high because one Somalian teenager only took pictures. We do not present the average number of pictures taken by the mothers because one mother took all 6 pictures. The participation per week represents the average number number of multimedia objects captured by the caregivers every week.

5.5.2 Overview of the Knowledge-Practice-Reflection Cycle

Since participants did not have control of external factors such as income, environment, and lack of transportation, I focused more on the tractable dietary issues. The dietary routines of the caregivers followed a knowledge-practice-reflection cycle (Figure 5.5). The dietary knowledge was based on their cultural upbringing and family experiences; the application and management of this knowledge was illustrated by their cooking and eating practices; and reflection was the resulting thoughts about their practices. In this cycle, reflection informs the participant's health to create an active feedback loop.

5.5.2.1 Knowledge

The videos and pictures revealed that the participants had a general knowledge of healthy and unhealthy foods. For example, some mothers were aware that vegetables were healthy and

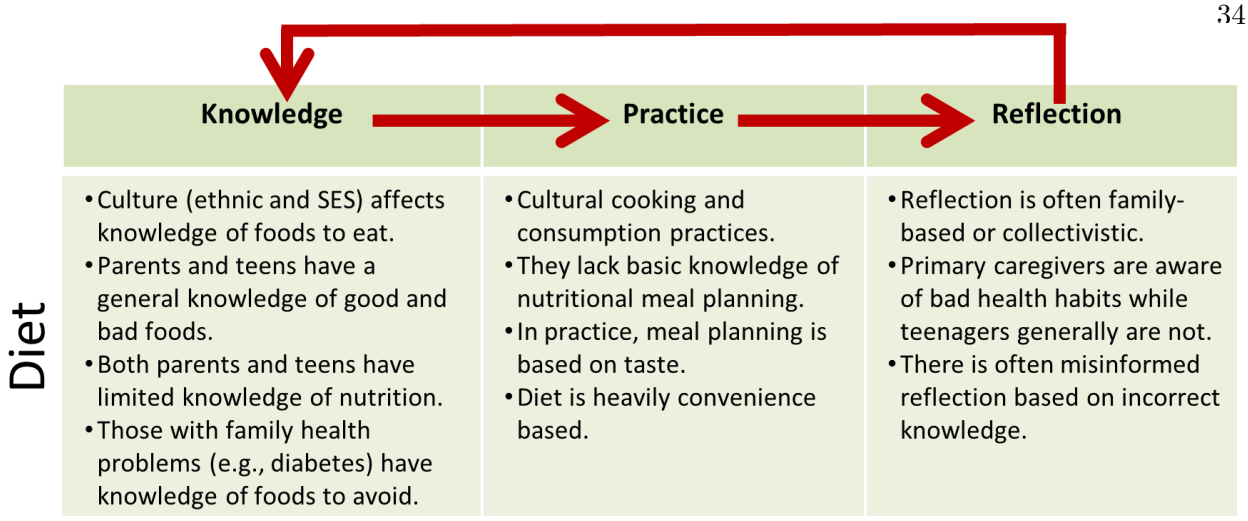


Figure 5.5: The Dietary Knowledge-Practice-Reflection (KPR) Cycle

used them in their diet, but did not know their nutritional value. PC4[1] discussed how salad was healthy: *"A really good healthy salad you should eat just as it is or with parsley, a little bit of salt and pepper or vinegar because a lot of the ranches and buttermilk are really high in fat."* (PV)[2] . PC3 mentioned that she attended cooking workshops held at the Bridge, *"... they are teaching how to eat more healthier... like not using too much grease and oil in our food and trying to use less seasonings ..."* (M3)[3] . PC3 further stated how she made sure to have vegetables in her meals, *"I cook a lot of healthy stuff ... I cook vegetables and stuff ... it is just a habit to make sure that we have some kind of vegetables going through our body ..."* (M3). The teenagers also expressed a similar general knowledge of diet. SC4[4] said, *"My mom tries to have fish a lot, but my brother doesn't like it, he eats beef, meat. My mom likes fish a lot because it is healthier."* (M2).

Despite the general dietary knowledge, the participants had little knowledge of nutrition (e.g., the role of carbohydrates and proteins). This is illustrated by PC2 in the following quote: *"Because I don't know too much about carbohydrates ... if I had more knowledge on what carbohydrates and all that was ... I would be like he ate this many carbs."* (M3). This was confirmed by another caregiver

[1] PC[N]: Primary Caregiver[#]. Throughout this dissertation I will use PC[N] to denote Primary Caregiver [#]. The numbering will start from 1 for all the chapters to maintain the privacy of the participants.
[2] PV: Excerpt taken from the transcript of a participant-captured video
[3] M[N]: Excerpt taken from the transcript of Nth meeting video
[4] SC[N]: Secondary Caregiver[#]. Throughout this dissertation I will use SC[N] to denote Secondary Caregiver [#]. The numbering will start from 1 for all the chapters to maintain the privacy of the participants.

Figure 5.6: SC4's school lunch

who added that this lack of knowledge can sometimes be a frustrating obstacle in understanding health.

During the MEIs, I observed that the participants' family health experiences affected their dietary knowledge. SC1's family minimized their sugar intake because her extended family had diabetes. In contrast, SC2 did not mention any adverse family health experiences and preferred sprinkling sugar over her fruits: *"I put sugar on everything. So yeah, every fruit has to have sugar on it. It has to be sweet. I shave my bananas up and then I put sugar on them and then when I eat apples I have like a little sugar salt-shaker and when I bite the apples I put a little sugar on it."* (M2).

A somewhat odd case was that some teenagers could not always visually identify the foods they ate at school. An example of this from SC4's school cafeteria is shown in Figure 5.6. In both cases, when prodded, she said: *"I have no idea."* (M2). If they are not able to identify what they are eating, how can they decide whether it is good or bad for their health?

Despite the lack of knowledge, there was one family who had healthy dietary habits. This particular Somalian family was of Muslim faith and, therefore, only ate halal food. Consequently, they did not eat at fast food restaurants readily available in their neighborhood.

5.5.2.2 Practice

Cooking and meal planning were the two predominant dietary practices captured in the findings. Two mothers planned their meals at the start of each day, one mother was not interested in planning her meals because she received food from the church where she volunteered, and the remaining mother thought she was not a planner type.

The mothers who planned meals daily usually planned in the morning. Meal planning in this case was based on their children's taste and not nutrition. The primary motivation behind this approach was to avoid food wastage. In answering the question as to how she decided what to cook, PC2 said: *"What the kids like. Because you know I can cook this big meal, go all out and they won't even want to eat it. So I'd rather cook something that they like versus to cook something that they will ... barely eat ... it all goes to waste."*(M2). Mothers also reused leftovers to reduce the waste, as shown in PC1's video: *"This is my lunch ... It is the enchiladas from leftovers ... I try to eat all the leftovers so that I don't waste any food because food is not cheap."* (PV).

Teenagers, on the other hand, did not plan meals; they primarily prepared them based on their own likes and dislikes. Answering the question as to whether she planned her meal, SC1 said: *"No, I just look in my refrigerator and I cook ... I think about what I wanna eat and they [family members] will eat that too. So that's how it works."* (M2). I found that some practices were unique to a particular family. For example, although some of the teenagers cooked what they liked, SC3 had to seek her mother's approval before cooking. SC3 said *"I was going to make something but then my mom said, 'No.' "* (M2).

I also observed that the surrounding culture induced a change in a recently immigrated Somalian family. Figure 5.7a shows SC3's refrigerator full of pre-packaged foods (pizzas and chicken nuggets), which is not native to her culture [30]. Another Somali family, however kept a healthy diet and mostly used home-cooked food (Figure 5.7b).

The mothers had some control over their schedule. They usually did not eat lunch, snacked the entire day, and cooked only for dinner because the children ate breakfast and lunch at school.

(a) SC3's refrigerator with prepackaged food

(b) SC4's refrigerator with home-cooked food

Figure 5.7: Effect of surrounding culture on recently immigrated Somalian families' diet

The teenage caregivers, on the other hand, had little control over their schedule. They snacked immediately after school and headed over to the Bridge Project. Upon returning, they cooked and had their dinner. One teenager remarked that she only saw her family on the weekends because the adults returned home from work late at night.

5.5.2.3 Reflection

Reflection played an important role in the participants' diet because it allowed them to become aware of their bad dietary habits. For instance, PC1 snacked after her children went to bed because she did not want to pass her bad habits to her children: *"They [children] were in the bed at that time. Because I don't want them to eat at night before they go to bed. So I don't want to pass on bad habits."* (M2). Similarly, PC2 mentioned about soda when discussing about grocery items: *"That's for the grownups, not for the kids."* (M2). This indicates that the mothers reflected on their bad dietary choices and attempted to pass on positive habits to their children. This is emphasized by PC1: *" ... I have to bring down the bad habits [of children]. But for them to change, I have to change."* (M3).

In teenagers, I observed cases of misinformed reflections. For example, SC3 said her family

generally ate fresh food, but her refrigerator, shown in Figure 5.7a, was full of pre-packaged foods. Similarly, in cooking chicken, SC1 remarked how healthy chicken was, but deep-fried it in oil. While chicken is healthy, the preparation practice used by SC1 was not necessarily healthy. It is a reflection based on insufficient dietary knowledge.

I also observed instances of family-based reflection on health that helped reaffirm good dietary habits in children. For example, in a cooking commentary video, PC3's child was cooking the food and when PC3 asked her, *"Are onions and bell peppers healthy?"* (PV), the child responded affirmatively. This video also illustrated cooking practices being passed down from mother to daughter. When the child questioned her mother about seasonings, the mother responded, *"We will put seasonings when we add water and bring it to boil."* (PV).

5.5.3 The Need and Motivation to Monitor Health

From the semi-structured interviews during Meeting 2, I found that most of the caregivers were interested in monitoring health. The most often cited reason was to improve eating habits and increase their fitness levels. While most mothers were interested in managing their children's dietary health, most of the teenage caregivers were more interested in monitoring themselves and their siblings' health. One mother was specifically interested in finding balance in her children's diet and activity levels, PC2 said: *"When they are active and busy and doing stuff they hardly want to eat to versus when they just want to lie on ground and watch TV and not do anything they will eat more. So I gotta find a way to not having them too over excited to where they don't wanna eat and too lazy that they want to eat too much. So I want to find the balance."* Whereas for teenagers, monitoring their parents' health was considered *"not cool"* and interestingly, they were most interested in monitoring their active siblings' health, not their siblings who were struggling with being active.

5.5.4 Preferred Health Metrics to Monitor

When asked what health metrics the participants wanted to track, the mothers were interested in tracking their family's food consumption, particularly the unhealthy foods. For example, PC1 mentioned that she wanted to replace unhealthy food in her diet with healthier food: *"Like what I was saying how I drink water, I drink Kool Aid - yeah it might be good for me but deep down it is not good because it is sugar ... If I can monitor what I eat and then look over it and then be like okay I'm going to take sugar out, and I'm going to take the fried foods out and substitute it with [motions with hand] you know what I mean? That for me can be good."*

Although diet was an important health metric, the mothers lacked in nutritional knowledge (carbohydrates, proteins, etc), PC2 said: *"Because I don't know too much about carbohydrates. If I had more knowledge on what carbohydrates and all that was [pause] I would be like he ate this many carbs."* Other health metrics included fluid intake and weight. With tracking weight, I observed a difference of opinion. While some caregivers found it useful, others were uncomfortable discussing it: As PC3 said *"...Unless you want typical people that will be like wooo so worried about the weight. It's just the weight type. Some people do worry about their weight and some just can't picture their weight or some just can't.. you know.. weigh themselves .. I think weight you shouldn't have in it. A lot of children get uncomfortable about their weight ..."* Teenagers on the other hand were interested in monitoring the effect of exercise on their weight. The African American teenagers regularly played directed sports including basketball and track and field and wanted to track calories and their performance during the sport.

5.5.5 Technological Platforms

I discussed the various technological platforms that were readily accessible and frequently used by the target low SES families. Two mothers preferred a mobile phone. The remaining two mothers preferred a computer because they had it at their home and used it regularly. Although most of the mothers generally spoke positively about technology, one mother was concerned with

the increasing use of video games by children, PC3 said, *"usually kids can play PS [PlayStation] everyday for hours. A game can actually take over their mind."* Prior to study, I thought that participants would prefer television as an important medium for the health management technology, however generally the participants thought that the lack of mobility made the television a secondary choice. PC1 mentioned a different reason for not preferring television: *"Even if it is on TV, there is always something else better than that to watch. So it's kind of TV is too much choices ..."*

For teenagers, three out of four said that they wanted any health monitoring application on a mobile phone because they were portable, and were easily accessible. For example, SC2 said: *"Cell phone ... Because most people don't have computers. And TV - I don't know. But the phones will be the solution because a lot of kids have cell phones."* The remaining teenager preferred a computer.

The participants said they would use the technology once a day in the afternoon, but not necessarily every day. Busy schedules were a major challenge for the mothers. PC4 said, *"I am interested in what you are doing. But my time, I don't know if I have the time to really get out and do it. I mean I do, but I don't."* Four participants said they would spend a maximum of 10 - 15 minutes using the application, three said 5 - 10 minutes, and one said 15 - 20 minutes.

5.5.6 Granularity of Capturing and Viewing Health Data

During the semi-structured interviews, I explored what granularity the participants desired to capture and view their health information. Two mothers wanted to capture health data daily, but wanted to view it on a weekly and tri-monthly granularity. Although mothers said that they would ideally capture their health data on a daily basis, they were skeptical about it given their busy schedules. PC1 said *"People like me - single parent [pause] I am kind of busy. And everyday I might forget one or two days. So I would do the week one."* Similar thoughts were resonated by PC2 who wanted to track her health data on a weekly basis. PC2 discussed how *"It would be either daily or weekly [pause] you know sometimes you cannot really do some things everyday"*

Similarly, teenagers also wanted to capture their health data everyday. However, unlike

mothers, two teenagers wanted to view their health data at daily granularity. The remaining two wanted to view it every other day or on a weekly level. SC1 said regarding monitoring her calorie consumption: *"... I would be interested in doing week wise so I know that I consumed in that week so I may calculate, add it all together and see how much I consumed over a month."*

5.5.7 Visualizing Single Health Data Stream

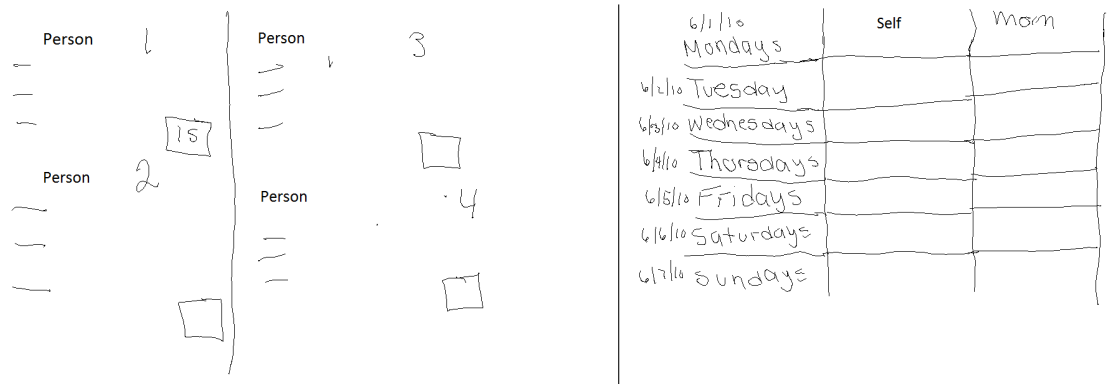
Once I established that the participants wanted to manage their health with technology, I explored health data visualizations in the prototyping sessions. A key factor in visualizing health metrics was information flow. The participants preferred a horizontal information flow for tracking the health metrics while they preferred a vertical information flow for representing time.

Although most of the participants found the calendar prototype (Figure5.1b) of limited use, two participants found it useful. SC1 mentioned that the calendar prototype reminded her about her mobile phone calendar where she conveniently pressed date-boxes to setup important reminders. PC1 suggested adding horizontal separators within the date-boxes to distinguish between the various health metrics she wanted to track. Of the caregivers who did not find this prototype useful, the primary reason was lack of space for entering the health metric information.

After discussing single health metric prototypes, I showed the participants multiple health metrics visualizations (Figure5.1c). Most of the participants found it useful, however two mothers mentioned that there was *too much going on* in these prototypes. Caregivers found that an overlaid line chart (Figure5.1d) was intuitive when the health metrics were related (e.g., weight and walking) and quantifiable. However, for unquantifiable metrics (e.g., foods consumed and exercise) they preferred a table comparison of the two metrics separately.

5.5.8 Visualizing Multiple Health Data Streams

Having explored visualizations of a single health data stream (health data of one individual), I discussed visualizations of multiple health data streams (health data of multiple people). Overall, the caregivers found value in multiple data stream visualizations because they were able to compare



(a) Prototype drawn by PC1

(b) Prototype drawn by SC3

Figure 5.8: Participant Drawn Prototypes (Note: Pictures have been anonymized)

their family members' health metrics. However, the caregivers were divided over the visualizations I provided. While some preferred a side-by-side comparison, others preferred a top-to-bottom comparison of health data streams (Figure 5.2a). Similarly, the participants were divided over whether multiple individuals' health information should be overlaid in a line graph.

Another important aspect of visualizations is finding the right balance between text and pictures. When the participants were asked whether they preferred textual or pictorial representations of health data, all of them desired textual information. PC3 mentioned that if the user did not know the spelling of a particular item, she could use the picture. Similarly, SC4 mentioned that pictures are good for people who have varying literacy. PC2 said *"... may be occasional picture here and there"*, but overall preferred textual information.

5.5.9 Prototype Interfaces Designed by the Caregivers

After I discussed the prototype designs, I asked the participants to design their own interfaces that visualized their health information. I found that majority of the participants preferred a tabular interface. Figure 5.8 shows representative drawings from PC1 and SC3. Both the drawings display multiple health datasets for different family members. PC1 (Figure 5.8a) preferred to compare four family members' health while SC3 (Figure 5.8b) compared her health with her mom's

health. SC3 also detailed her desired data granularity by providing all the days of a week. An interesting problem arose during the prototyping activities was how to visualize aggregation of food data. Although most of the participants found it difficult to visualize, SC2 suggested to distinguish different foods by a color code. For example, green color could represent vegetable intake while red color could represent meat intake. These colored foods could be shown in a stacked bar chart to represent intake at a daily, weekly, or monthly granularity.

5.6 Discussion

To answer RQ1, I successfully employed a participant driven method, the MEI, to explore everyday health routines of a low SES population. The benefit of using MEIs over other needs analysis methods is that it shifts the balance of power from the interviewer to the interviewee; since the participants are the authors of the content, they feel a sense of ownership that makes them comfortable while discussing their everyday health habits. Moreover, while discussing the videos and pictures, the participants get an opportunity to reflect on their lifestyle, providing more contextual information and thereby allowing for a deeper analysis of the data. Unlike shadowing, where participants are conscious of researchers observing them and that is likely to affect their actions, MEIs protect participants' privacy where they only record information that they want to share. The HCI community can benefit from the MEI method because it provides deeper insight into participants' motivations and the rationale behind their everyday choices.

The usage pattern statistics for this study suggest that the participants will use a mobile phone-based health routines-capturing application with no feedback 2 to 3 times a week. During the study, the participants confirmed that they would use their own mobile phones for managing their health because they already used it in their daily lives. Since most of the meals captured were dinners, evening hours may be the best time of day for a dietary sociotechnical intervention.

A nascent theme was how participants reflected on what they saw in the videos, either while recording something that reminded them of health or when reviewing the videos with me during interviews. They noticed the impact of actions, for example, watching their children put too much

seasoning in a dish or realizing how hard they were breathing while walking. This reflection, identified in the KPR cycle, is a key aspect of inducing positive change and in turn informs their everyday health, knowledge, and practice. Any successful dietary sociotechnical intervention needs to utilize this positive feedback loop for effective health outcomes.

5.6.1 Diet and Technology

When discussing health related activities with low SES populations, diet was the dominant topic. Thus, I believe that, in order to improve the target populations' health, effective sociotechnical dietary interventions need to be designed. Although there are many dietary and nutrition applications available from the commercial (e.g., calorieking.com and myfitnesspal.com), government (e.g., choosemyplate.gov), and academic [202] sectors, they do not take into account the needs of low SES populations: specifically, limited resources, culturally influenced diets, lack of nutritional knowledge, and access to healthy foods. For example, providing specific nutritional knowledge might not be as helpful in motivating change. In discussing a potential nutritional application, PC1 commented, *"That is how I am. If I don't understand it, I will get frustrated and I won't use it."*(M3). Therefore, any technology needs to educate or abstract nutritional information so that it is easy to understand. For example, star icons can provide a weighted representation of nutritional values [42].

5.6.2 The Role of Culture

While acknowledging different ethnic backgrounds, it is also necessary to consider the confluence of different cultures. The local geographic culture tends to dominate native culture over time in children who are born into one culture but grow up in another [71]. Immigrants increasingly supplement their cultural diet with non-native processed foods [30]. One immigrant Somalian family was using more local foods in their diet (see Figure 5.7). Based on this, I propose to retain the best practices of a culture's traditional diet while adopting healthy foods from the host country. For example, one Somalian family had a healthy diet compared to other families, despite their cur-

rent economic situation and environment. The health practices of the healthy family [173] can be modeled and introduced to other Somalian families so that they can include these everyday habits to improve their health. Since cultures are ethnocentric by nature, a healthy family's habits can be used as an example to motivate positive dietary change for a particular culture. In this case, researchers can create a mobile phone application that displays picture storyboards or videos of the healthy family discussing healthy dietary tips particular to each culture. This method is also useful for families that suffer from chronic illnesses.

5.6.3 Gradual Change

The results showed that participants' cooking and eating choices were based on their taste. To improve their dietary habits, their food preferences should be considered. The technology can be used to recommend gradual reduction of unhealthy food items. One way of visualizing this gradual change can be adopted from Pollak and colleagues [167], where an individual's intake impacted a virtual pet's emotional state. More research is needed to optimize this solution for taste. In our prior study [190] in the same community, the participants discussed more physical activities. In this study however, in spite of logging exercising, they still perceived themselves as "big". Based on the diets logged in this study, I hypothesize that their limited physical activity is not enough to burn the calories consumed. Because I advocate a gradual change in their diet, the participants will not witness rapid positive results of their new lifestyle. This can lead to a lack of motivation toward their exercise goals. Technologies are needed that help visualize results until the body catches up to make participants aware of these imperceptible physical changes.

The findings also suggest a need for technologies that provide timely feedback to support long-term dietary change. This is evidenced by PC1's self-reported addiction to food, where she snacked after her children went to bed. Despite knowing that it is bad for her health, she was not aware how this repeated instance negatively contributed to her long-term health. Conversely, PC2 walks her children to school, but does not consider it as exercise. I wish to design technology that shows how every action, whether positive or negative, affects everyday health. An interesting avenue

of research that has the potential to fill this gap is wearable technology (e.g., pedometers). Most mobile phones today contain sensors (e.g., accelerometers) that can be used as a wearable device to monitor and share timely information at the right time and place to encourage opportunistic activities. As opposed to structured exercise, a person incorporates activities into their everyday lives (e.g., taking the stairs instead of the elevator) in an effort to increase overall activity. Research has shown that this can often lead to structured exercise [55].

During the MEI, the participants were seen to snack a great deal and had a broad definition of snacks that included pizza and burritos. Rather than designing technology to improve the diet as a whole, their diet might be improved gradually, by designing a sociotechnical intervention to improve a subset of their diet such as snacking.

This study revealed that the low SES caregivers wanted to monitor their own health and their family's health. Although prior studies have confirmed that individuals wanted to monitor their own health [21], the literature is distributed on the issue of sharing health information with family [21, 91]. While we know that the caregivers from the target population were interested in monitoring their family's health, more work is required to explore the subtle privacy concerns related to various health metrics.

5.6.4 Health Management Application

The MEI study also addressed RQ2, which was to identify opportunities to design appropriate sociotechnical intervention. Based on the interview findings, the most appropriate health management application for this low SES population would be a mobile phone application that would visualize a single health metric for one person with the ability to capture and view health data on a daily basis. While this is only the bare minimum, the caregivers wanted scalable interfaces that would visualize multiple health metrics for different individuals. Although these features are supported by existing PHRs like Microsoft HealthVault (healthvault.com), this study suggests that low SES populations would find the interface to be a cognitive overload. Moreover, one of the participants found the line chart - commonly used in PHRs to track health metrics - difficult to

understand. Further studies, however, are needed to confirm this hypothesis.

In the results, I presented the various health metrics that the participants wanted to track, but the common metric between both mothers and teenagers was diet. Any health management application should have intuitive visualizations that represent dietary data. Although we might assume that weight is a natural selection as a health monitoring metric, I found that one mother participant was extremely sensitive to capturing and tracking her weight. On the other hand teenagers were enthusiastic about tracking their weight. When designing health management technologies, the informaticians and designers need to understand sensitivities of different types of caregivers towards various health monitoring metrics. Not only do we need to be aware of these limitations but we can also design visualizations that leverage on the opportunities provided by users' preferences. For example, we can design interfaces that visualize the body-image of teenagers to encourage them in using the health intervention technologies.

The technology readily available and preferred by most of the caregivers were mobile phones. It might come as a surprise that the low SES population prefer mobile phones since a common perception is that they would not have phones. However, this is far from reality - in fact, low SES populations have been found to spend a greater time on mobile phones as compared to their higher SES counterparts [198]. Moreover, with the advent of Android SDK, it has become feasible for academic researchers to design and evaluate native mobile applications without going through the cumbersome process of verified signing.

During the study, I asked the participants whether they wanted text or pictures to visualize health information in the prototype interfaces. Although research has shown that pictures help building a mental model of textual information [82, 129], most of the participants preferred only text. However, I believe this preference is based on their everyday interaction with technology - mobile phones - which they regularly use for text messaging. Other reasons could be caregivers' limited exposure to picture-based interfaces. Although caregivers wanted text-based interfaces on mobile phones, this might not be conducive given the participants' busy schedules. Prior work in health visualization has shown that pairing images with health metrics has provided much needed context

to help patients reflect on their health [76]. For example, Smith et al. [76] investigated pairing blood glucose values with images of daily routines to help diabetes patients understand the relationship between their everyday habits and glucose levels. From a family perspective, researchers have designed graph-based visualizations to compare different family members' suggestions to improve their health lifestyles [49]. These visualizations aided discussion among the family members and helped in establishing a collective goal.

Aside from designing traditional table-based and graph-based interfaces [6], we need to explore interfaces where health information is understood in a single glance. The HCI community is already working on these *glanceable* displays [56, 167] - UbiFit Garden, for example is a mobile phone-based application that visualized individuals' physical activity by a glanceable garden metaphor. Similarly, Pollak et al. [167] designed a mobile phone based application that related the healthiness of users' diet to a virtual pet's emotional state. For the target population, however we need to explore how these glanceable interfaces could be designed considering their low SES context.

5.7 Conclusion

I addressed RQ1 and RQ2 in the MEI study, where I was successful in capturing and understanding everyday health routines of the target population. My findings revealed that the participants' health was affected by numerous factors. Some of these were external factors (e.g., neighborhood environment), on which the participants had limited control. However, the most influential factor affecting the health of the target population was their diet, particularly their poor snacking habits. The use of videos helped me discover how the participants' dietary behaviors followed a knowledge-practice-reflection cycle. Although culture played the dominant role in this cycle, there were various themes - obtained from the videos and pictures captured by the participants - that fell in the different stages of the cycle. Some of these themes included limited nutritional knowledge, meal planning based on waste versus taste, and family-based collectivistic reflections on dietary practices. I also found that this population has access to different types of

technologies, however their preferred technological platform for a sociotechnical health intervention are mobile phones because they are pervasive and can be used anywhere.

I conclude that there are opportunities for productive sociotechnical interventions in the lives of the underserved. The multicultural dynamics present in the population poses some interesting challenges in the design of effective sociotechnical interventions. Appropriate technologies need to induce gradual change towards healthier dietary practices while providing a feedback to keep the users motivated. Finally, I urge the design community to engage into community based participatory research where all the stakeholders - policy makers, HCI designers, social scientists, and low SES families - should work together to design effective technological interventions that induce and maintain a positive change in the health of low SES populations.

Chapter 6

Prototyping

Once I completed the needs assessment with the MEI study, it was clear that I had to design a mobile phone application that would provide users with the ability to manage their family snacking. This resulted in RQ3: how do we visualize the snack consumption? Before starting the conceptual design, I researched various health behavior change theories. I selected the social cognitive theory, health belief model, elaboration likelihood model, transportation theory, and the precaution adoption process model because these theories provide a concrete foundation for a sociotechnical framework to improve health behaviors. How we implement these theories in the prototype design is always open to discussion because different individuals interpret the theory-design relationship differently. The results of the prototype evaluation study were published in [112]. The novel results reported in this dissertation include section 6.5.1.3, 6.5.2.6, and 6.5.3.3 where I discuss participants' preferred application features, reminder systems, and social network gaming. I also added section 6.6.5 in discussion where I present challenges in evaluating gaming prototypes.

6.1 Behavioral Change Theories

In this section, I will discuss some of the prominent theories including the social cognitive theory (SCT), theory of reasoned action (TRA), transtheoretical model (TTM), precaution adoption process model (PAPM), elaboration likelihood model (ELM), health belief model (HBM), and the transportation theory.

6.1.1 Health Belief Model

The HBM [53] is one of the earliest behavioral theories that explained how individuals change their health behaviors. The HBM illustrates that an individual may change her behavior to prevent an illness based on threat perception and behavioral evaluation. The threat perception includes beliefs in perceived susceptibility and assessment of the severity of the illness. Similarly, behavioral evaluation includes beliefs in perceived barriers and perceived benefits of performing the behavior. HBM has been primarily used for preventive health behaviors, sick role behaviors, and clinical use. The preventive health behaviors mostly include interventions to improve diet and physical activity.

6.1.2 Social Cognitive Theory

The SCT [53] describes how individuals' perceived self-efficacy coupled with sociostructural factors and outcome expectations affect the individuals in achieving their goal and bringing about a behavioral change. The perceived self-efficacy is influenced by personal accomplishment, vicarious experiences, verbal persuasion, and emotive sources. Prior to the work leading to SCT, researchers primarily attributed an individual's learning to her personal trial and error experiences. Bandura's work [12] on self-efficacy displayed that individuals learned from experiences of other people and did not merely copy the behaviors, rather exhibited modified behavioral patterns. Many technological interventions [8, 101, 132] based on SCT connected self-efficacy to efficacy expectations (belief that one can produce a certain behavior) and outcome expectations (whether a certain behavior will result in a certain outcome).

6.1.3 Theory of Reasoned Action

The TRA [53] proposes that an individual's behavioral intention is influenced by her attitude towards the behavior and the perceived reaction of other people towards the behavior (subjective norm). Both attitude and subjective norm are given weighted values since they depend on the individual and his environment.

6.1.4 Elaboration Likelihood Model

The ELM [53] is an attitude model that describes how low elaboration and high elaboration affect individuals' attitudes towards a persuasion. The persuasion may be achieved through a great deal of thought (the central route), or through a lower cognitive processing (the peripheral route). Attitudes achieved through the central route are more stable and permanent, while the attitudes formed by the peripheral route are more susceptible to counter-persuasion.

6.1.5 Transtheoretical Model of Behavioral Change

Most of the behavioral theories earlier than TTM were focused around weighing different variables of an individual's behavior. Stage theories were introduced that categorized individuals' behaviors in different stages. For example in TTM [53], individuals are categorized in different stages of behavioral change according to their readiness to adopt a certain behavior. The TTM provides opportunities for researchers to create strategies specific for individuals in a certain behavioral stage to encourage them in achieving and maintaining a healthier behavior. The five behavioral stages of TTM include (1) precontemplation, (2) contemplation, (3) preparation, (4) action, and (5) maintenance. Numerous researchers have used TTM to model individuals' eating [24, 90, 101] and physical activity behaviors [131].

6.1.6 Precaution Adoption Process Model

Like TTM, the PAPM [207] is also a stage theory, however it has seven stages - two more than TTM. The PAPM stages include (1) unaware, (2) unengaged, (3) deciding about acting, (4) decided not to act, (5) decided to act, (6) acting, and (7) maintenance. The major difference between TTM and PAPM is that "precontemplation" stage of TTM is divided into "unengaged" and "decided not to act" stages in PAPM. The "decided not to act" stage is an off-shoot of the main model sequence. The PAPM also includes an unaware stage, where the individual is completely unaware about the issue. The application of PAPM has been limited as compared to the widespread usage of TTM. Some researchers [24, 155] have used PAPM to understand and improve dietary behaviors

of individuals.

6.1.7 Transportation Theory

The transportation theory [83] is a relatively newer theory which suggests that individuals' beliefs and attitudes are affected whenever they engage in an immersive narration. With the recent advancements in computer technologies, different researchers are turning towards multimedia games that can have a positive impact on players' health [17]. According to transportation theory, when an individual experiences an immersive narration, she makes some decisions in the narrative world that induces a change when she returns to the world of origin.

6.2 Prototypes

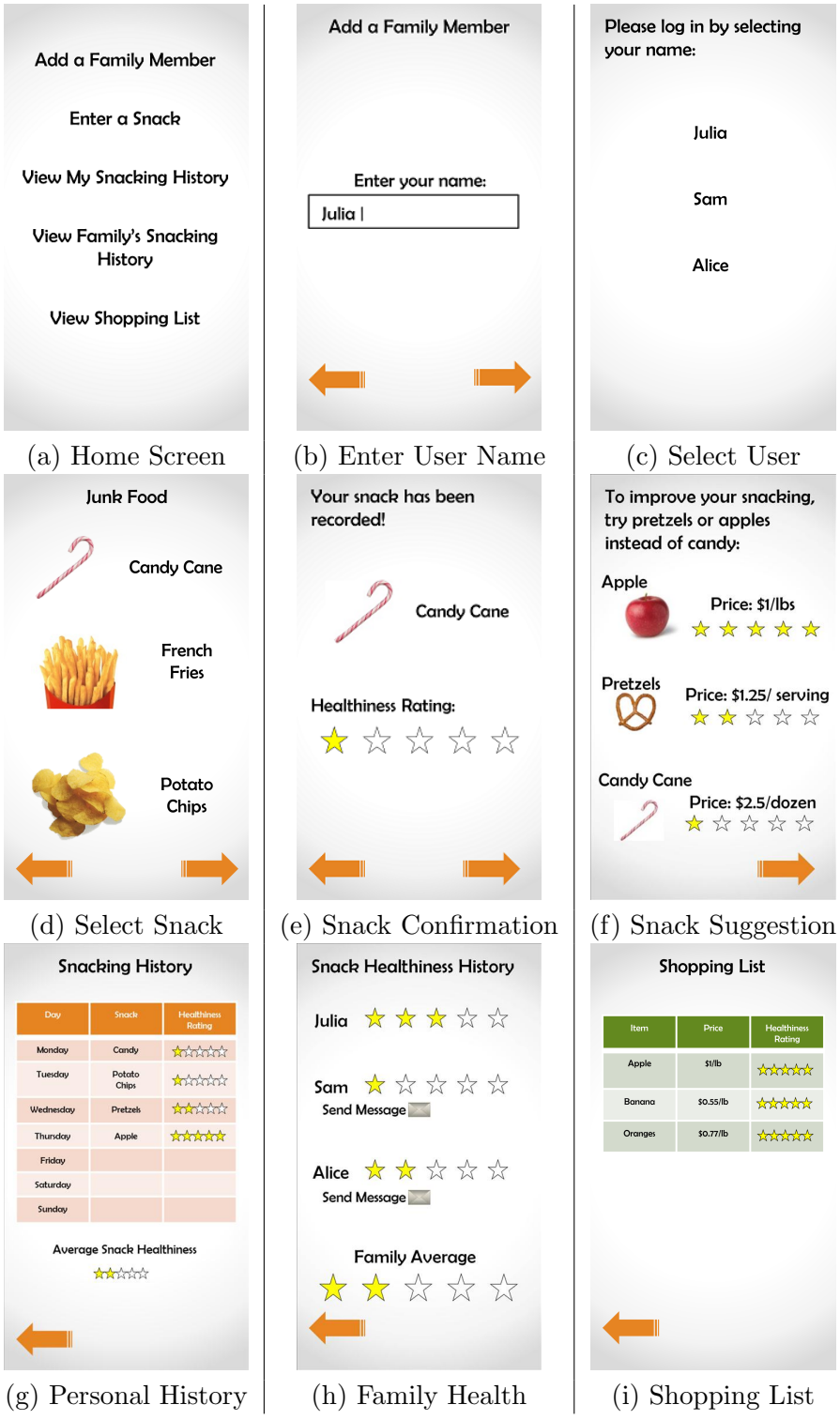
The four high-fidelity prototypes were designed as touchscreen-based mobile phone applications because the needs assessment revealed that the participants wanted the technological intervention on a mobile phone. As shown in Table 6.1, all the prototypes were informed by established behavioral-change theories and had some basic features in common that provided users the ability to: (1) enter snacks; (2) receive feedback on snack healthiness; (3) view individuals' snacking history; (4) view family snacking healthiness. The first two prototypes discussed below are non-gaming while the last two are gaming applications. All the prototypes were internally evaluated and modified using multiple cognitive walkthrough [130] iterations.

6.2.1 Snack Manager

Snack Manager was based on SCT; the Snack Manager design incorporated SCT by providing users the ability to view the snack healthiness of their family members and send messages to each other to encourage healthy snacking habits. The Snack Manager prototype design was informed by my prior work where I found that the low SES families did not want to waste food and risk money on new food items [110]. Based on these findings, the prototype provided suggestions to users within a price threshold to replace their current snack with a healthier snack. The healthier

Table 6.1: Behavior change theories and corresponding prototype interface characteristics

Behavior Change Theory	**Interface Characteristics**
Health Belief Model	**Snack Educator:** - Displayed unhealthy snack's potential negative impact on user's heart, body, and teeth, and compared it with a healthier snack
Social Cognitive Theory	**Snack Manager:** - View snack healthiness of their family members - Send/receive messages to/from other family members to encourage healthy snacking habits **Snack Educator:** - View snack healthiness of their family members **Health Heroes:** - View snack healthiness of their family members **Lifespan:** - View snack healthiness of their family members
Elaboration Likelihood Model	**Snack Educator:** - Encouraged central route decision-making by visually categorizing an individual's long-term snack consumption into healthy, average, and unhealthy
Transportation Theory	**Health Heroes:** - Visualized immersive narration of Health Heroes fighting against Taco Belly where Health Heroes' powers depended on user's snack healthiness **Lifespan:** - Visualized immersive narration where game character's success in life depended on user's snack healthiness
Precaution Adoption Process Model	**Lifespan:** - Different stages of game character's life corresponded to PAPM stages



(a) Home Screen (b) Enter User Name (c) Select User

(d) Select Snack (e) Snack Confirmation (f) Snack Suggestion

(g) Personal History (h) Family Health (i) Shopping List

Figure 6.1: Snack Manager Prototype informed by SCT

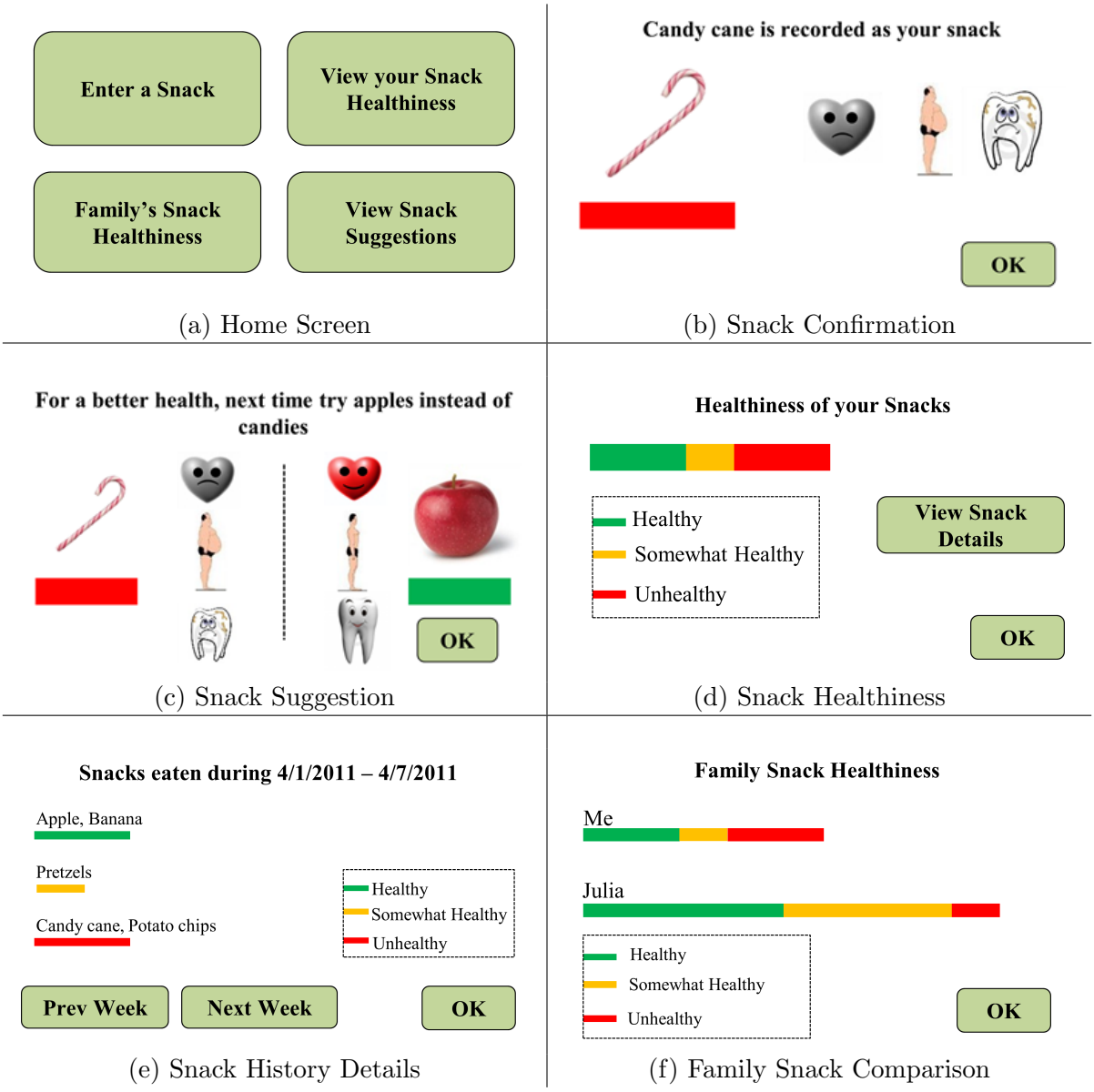
snack was either within the same product category as the current snack, or it was a snack that the low SES families preferred.

The home screen, shown in Figure 6.1a, lets users navigate to different screens of Snack Manager. Users could create a new user (Figure 6.1b) or select the family member (Figure 6.1c) whose snacks they wanted to manage. Once the user was selected, they could enter snacks for that user as shown in Figure 6.1d; a confirmation screen would appear to confirm the selection of the snack (Figure 6.1e). If the snack was unhealthy, the snack suggestion screen (Figure 6.1f) displayed the healthiness of the current snack and suggested snacks in a star rating system. The stars, which were paired with the snack prices, were used to abstract health information since prior work showed that participants did not understand dietary nutritional values (e.g., proteins, carbohydrates). Finally, the users could view their snack history (Figure 6.1g), their family's snacking healthiness (Figure 6.1h), and a convenient shopping list with all the snack suggestions provided by Snack Manager (Figure 6.1i).

6.2.2 Snack Educator

The Snack Educator prototype, shown in Figure 6.2 was based on SCT, HBM, and ELM. The Snack Educator incorporated HBM by displaying unhealthy snack's potential negative impact on the user's heart, body, and teeth, and comparing it with a healthier snack. The Snack Educator also used ELM; I designed the Snack Educator to capitalize on central route decision-making by visually categorizing an individual's long-term snack consumption into healthy, average, and unhealthy.

The home screen shown in Figure 6.2a, provided users the ability to navigate to different modules of the application. After the user entered a snack, the system displayed the snack's potential impact on the user's heart, body, and teeth as shown in Figure 6.2b. The following screen, shown in Figure 6.2c, suggested a healthier snack and compared the three health indicators for both the entered snack and the suggested snack. The user could view his overall snack history (Figure 6.2d) and his detailed snacking history (Figure 6.2e). The users could also compare their snack healthiness with their family members (Figure 6.2f). The snack healthiness was represented



(a) Home Screen

(b) Snack Confirmation

(c) Snack Suggestion

(d) Snack Healthiness

(e) Snack History Details

(f) Family Snack Comparison

Figure 6.2: Snack Educator Prototype informed by SCT, HBM, and ELM

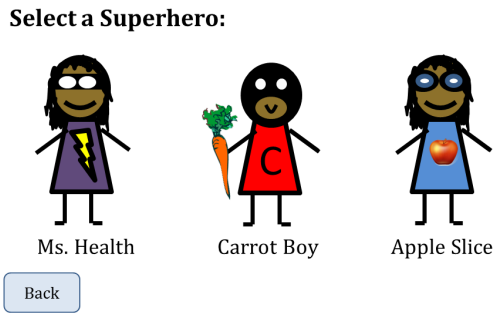
by a bar that consisted of different colors corresponding to the healthiness of the snack with green and red being healthy and unhealthy, respectively.

6.2.3 Health Heroes Prototype

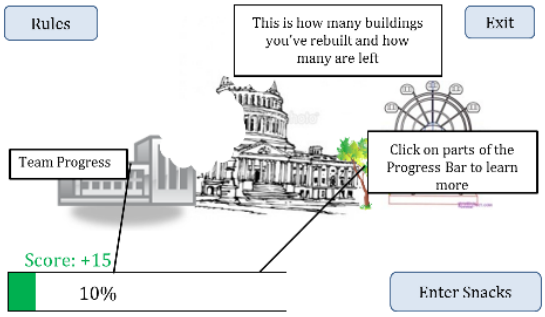
The Health Heroes prototype shown in Figure 6.3 was a gaming application that was based on SCT and transportation theory. In the game, the user selects a health hero character (Figure 6.3a) who has to defend the city of Denver against the onslaught of Taco Belly - the main villain. The game starts with Taco Belly causing destruction in Denver; the home screen (Figure 6.3b) shows ruined buildings that need to be rebuilt. Game progress was also shown in the form of a progress bar at the bottom of the home screen. The Health Heroes need to gain different superpowers such as invisibility (Figure 6.3d) and laser attack to fight Taco Belly and rebuild the city. These superpowers can be gained by increasing healthy snack points, which in turn are obtained by eating healthy snacks. As the player eats healthy snacks, she can successfully counter Taco Belly's attacks that include adverse events comprised of unhealthy snacks, e.g., turning Denver water into soda or throwing huge blocks of butter over Denver. As the game progressed, the users are presented with different fight sequences between the Health Heroes and Taco Belly as shown in Figure 6.3c. The Health Heroes prototype also has a multi-player mode where different family members play the game and coordinate to form a team of Health Heroes to fight Taco Belly. The players can view their individual snacking points breakdown (Figure 6.3e) and team status (Figure 6.3f). Once the city buildings rebuild, the players need to keep eating healthy snacks to counter a surprise attack by Taco Belly.

6.2.3.1 Lifespan

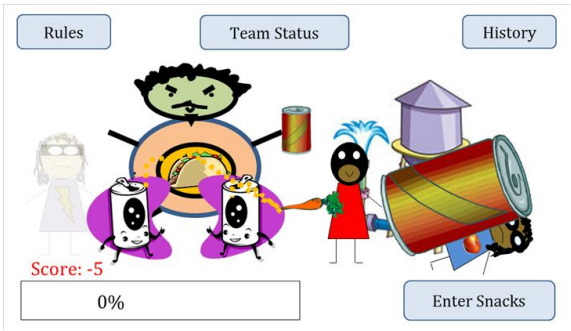
The Lifespan prototype, shown in Figure 6.4, was a gaming application based on SCT, transportation theory, and PAPM [53]. The Lifespan prototype used an animation-based narration to encourage healthy eating where the player selected a game character (Figure 6.4a) whose progress in life was related to the healthiness of a player's snacks. The character went through different stages



(a) Health Heroes Selection

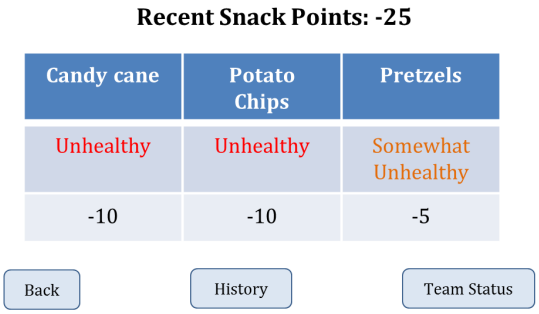


(b)Home Screen

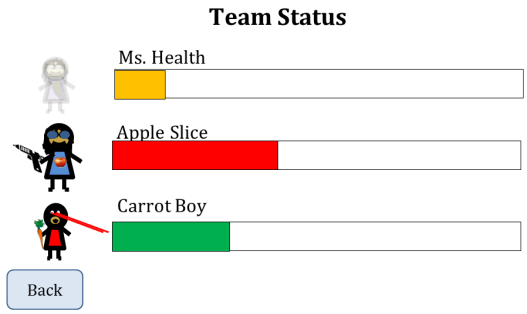


(c) Health Heroes fight Taco Belly

(d) Player gains invisibility

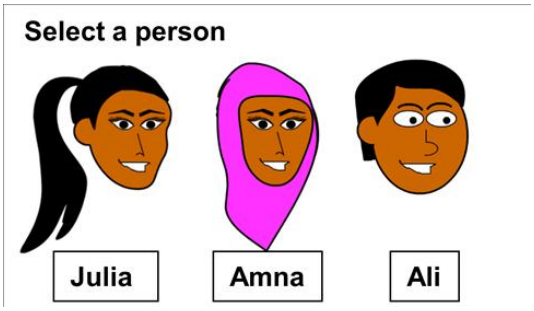


(e) Individual Snack History

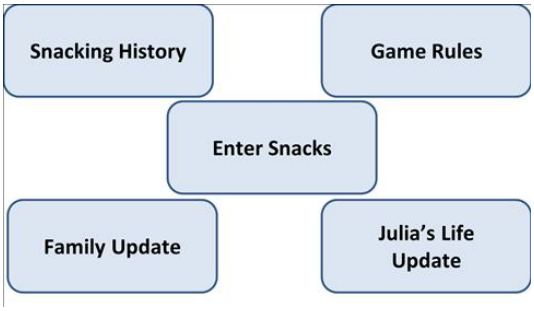


(f) Family Snack Comparison

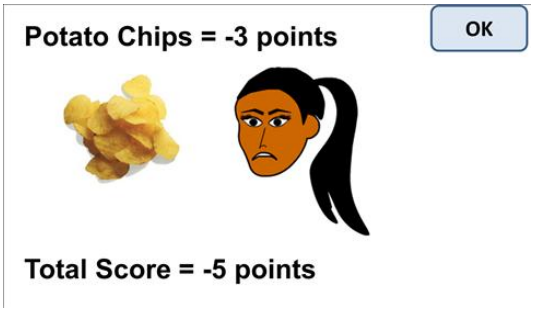
Figure 6.3: Health Heroes Prototype informed by SCT and Transportation Theory



(a) Character Selection

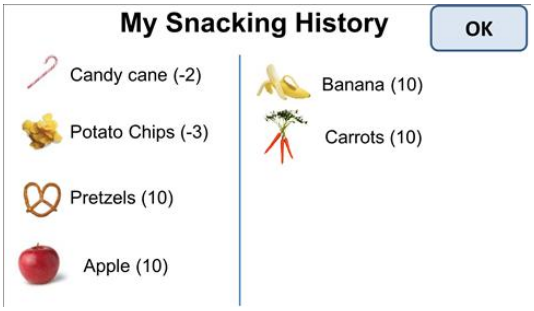


(b) Home Screen

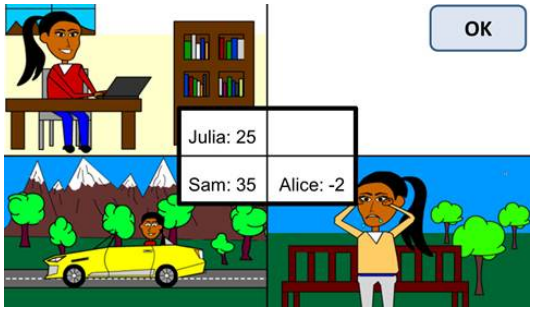


(c) Feedback on unhealthy snack

(d) Player gets a job



(e) Personal Snack History



(f) Family progress

Figure 6.4: Lifespan Prototype informed by SCT, PAPM, and Transportation Theory

of life, which was informed by the stage-based PAPM that categorizes an individual's behavior in seven different stages: (1) unaware; (2) unengaged; (3) deciding about acting; (4) decided not to act; (5) decided to act; (6) acting; and (7) maintenance.

In the Lifespan game, I translated the PAPM stages to the game character's progressive life stages. The game goal was to gain enough health points to have the character get an education, job, house, and car.

Since past study participants were African Muslims, I designed culturally sensitive characters, such as one wearing a hijab. The home screen shown in Figure 6.4b presented users with various navigation option, once the player entered a snack, she would view the game character's reactions (Figure 6.4c) followed by an animation highlighting the character's progress in life. Players moved to the next stage by eating healthy snacks and gaining a predetermined amount of health points. For example, Figure 6.4d shows the game character getting a job. Once the players reached the final stage, they had to maintain healthy snacking; otherwise they would fall back to the previous stage. As shown in Figure 6.4e, players could view their snacking history with pictures of snacks and health points. Players could also compare the snack healthiness of different family members by viewing the snapshots of their family members' characters (Figure 6.4f).

6.3 Participant Demographics

I recruited 26 participants, including 8 primary caregivers and 18 secondary caregivers. The primary caregivers included 7 females and 1 male - their average age was 36.1 years (s.d.= 9.4 years). Five of the primary caregivers were African American, while the remaining 3 were Hispanic. Five primary caregivers owned a computer and all of the primary caregivers had used a computer and had access to a computer elsewhere. Six primary caregivers owned a mobile phone (5 smartphones) and used it daily. The 2 that did not own mobile phones, however knew how to use them.

The 18 secondary caregivers were equally split gender wise: 9 males and 9 females. The average age of secondary caregivers was 14.6 years (s.d.= 1.6 years). Thirteen secondary caregivers identified themselves as Africans, 3 as Hispanic, and 2 as African Americans. Thirteen secondary

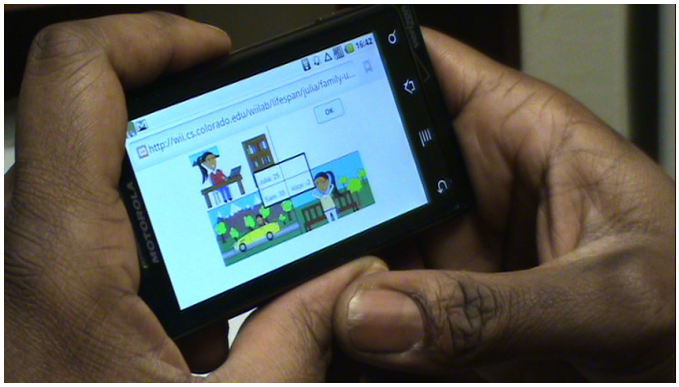


Figure 6.5: Participant using a Motorola Droid phone for prototype evaluation

caregivers had a computer at their home; all of them had access to a computer elsewhere. Five secondary caregivers owned a mobile smartphone. All secondary caregivers mentioned that they knew how to use a mobile phone.

6.4 Methods

After obtaining Institutional Review Board approval, I recruited participants with the assistance of the Bridge Project personnel. To qualify for the study, the participants needed to be able to communicate in English.

In the MEI study, I found that although primary caregivers readily provided feedback, the secondary caregivers were a bit hesitant in communicating with us. Therefore, for this study, I used subjects-in-tandem (sometimes called co-discovery) where I asked the Bridge Project personnel to pair the teens so that they felt more comfortable talking to researchers.

After collecting the demographic information, the participants were provided a task list (see appendex) and a scenario. Participants had to (1) set up the application, (2) enter multiple snacks, (3) view individual snack history, and (4) view family snack history. I used a Motorola Droid touchscreen mobile phone for the study as shown in Figure 6.5. Prototypes were presented in random order. Since the secondary caregivers were in pairs, I asked them to alternate using the mobile phone after each prototype.

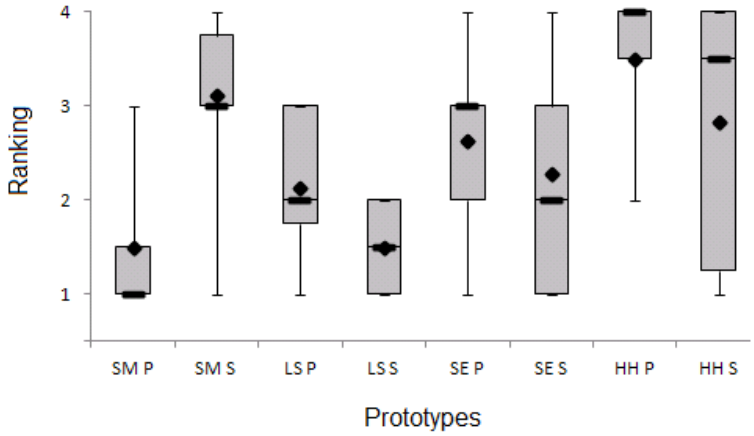


Figure 6.6: Comparison of Primary (P) and Secondary Caregivers' (S) Prototype Rankings; SM=Snack Manager; LS=Lifespan; SE=Snack Educator; HH=Health Heroes; Diamond=Mean; Dash=Median; Ranking is based on a 4 point inverse scale where 1 is the highest ranking and 4 is the lowest

I also asked questions to understand which prototype features they liked or disliked, the reason behind their choices, and how I could improve the prototypes. Following the four prototypes, I provided the participants a post-study questionnaire (see Appendix E) where I asked them to rank the various prototypes and rate the importance of the application features. Participants could provide the same rank to multiple prototypes.

I presented the following application features and asked the participants to rate them on a five-point Likert scale; the application should (1) educate people about healthy and unhealthy snacks, (2) be fun to use, (3) require minimum time for usage, (4) be easy to use, (5) present effect of snack on individual's health, (6) have goal setting capabilities, (7) suggest healthy snacks, (8) have snack prices, (9) track and present snacks, (10) have family-messaging capabilities, (11) display entire family's snack healthiness, and (12) should display multiple healthy snack alternatives.

All study sessions were conducted at the Bridge Project facility. Each session was video recorded with participants' consent and lasted for 90 minutes. A fifteen dollar retail store or supermarket gift card incentive was provided to the participants at the end of the session.

6.5 Results

Overall, I found that primary caregivers preferred applications that were well-organized and provided them a straight-forward mechanism to manage their snacks, whereas secondary caregivers favored applications that were game-like and engaging. The semi-structured interviews provided interesting insights into reconciling these two approaches for a family-based intervention. I further expand on these ideas starting with the findings from the post-study questionnaire.

6.5.1 Caregiver Preferences

6.5.1.1 Primary versus Secondary Caregivers' Preferences

The post-study questionnaire results (Figure 6.6) highlighted key differences between the two types of caregivers. Most of the primary caregivers preferred Snack Manager, which lay in stark contrast to secondary caregiver rankings where 75% gave it a low ranking. The Lifespan prototype was consistently preferred by both types of caregivers. In contrast, Snack Educator received mixed rankings from both primary and secondary caregivers. None of the primary caregivers favored Health Heroes, however half the secondary caregivers preferred it.

6.5.1.2 Gaming, Non-Gaming, or a Combination of Both?

In the post-study questionnaire, I also asked participants whether a snack management application should be a game, non-game, or a combination of both. The primary caregivers did not want a gaming application and preferred either a non-gaming (N=4) or a hybrid (N=4) approach. This is in line with the prototype rankings where there was a tendency among primary caregivers to favor non-gaming applications, specifically Snack Manager and Snack Educator. On the contrary, only 1 secondary caregiver wanted a non-gaming application, while the rest favored having a gaming component.

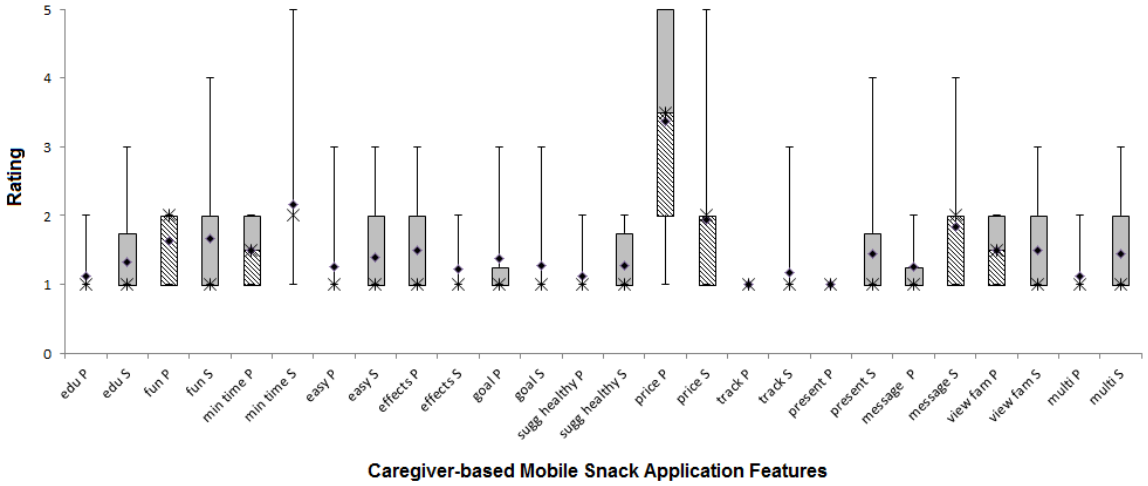


Figure 6.7: Caregiver based rating of different mobile snack application features; Diamond=Mean; Dash=Median; P=Primary Caregiver; S=Secondary Caregiver; edu=educates people about healthy snacking; fun=fun to use; min time=requires minimal usage time; easy=easy to use; effects=displays potential effects of bad snacks on health; goal=goal setting; sugg healthy=suggests healthier alternative snacks; price=displays snack price; track=tracks snacks; present=presents snack history; message=ability to message family members; view fam=view family snacking healthiness; multi=provides multiple healthy snack choices

6.5.1.3 Application Features

As shown in Figure 6.7, the primary and secondary caregivers rated most of the application features high, ranging from 1 - 2 on the five-point Likert scale (1 being highly preferred). To my surprise, displaying snack price was not preferred by the participants with most of the primary givers rating it higher than 3. Price was also the only feature that was rated as 5 (lease preferred) by at least one primary and secondary caregivers. The primary caregivers' highest preferred features included ability to track and present snack consumption - it was rated as 1 by all the primary caregivers. The primary caregivers also highly rated the ability to educate users about healthy snacks, minimal usage time, messaging, and multiple healthier snack alternative suggestions. In contrast to primary caregivers, none of the mobile snack application features was rated 1 by all the secondary caregivers. The top rated features by the secondary caregivers included effects of unhealthy snacks on health and healthier snack suggestions.

6.5.2 Snack Manager

During the prototype evaluation sessions, I discovered that primary caregivers preferred Snack Manager over the other applications because of its well organized interface, family messaging capabilities, and intuitive visualizations to understand snack healthiness as PC8[1] summarized, *"It just seems more organized and it has a better layout and a better understanding of ... what you are trying to reach [goal]."* Similarly, PC4 said: *"I like the organization details on it. I can keep a better record of actually what I'm eating."*

6.5.2.1 Messaging

The primary caregivers emphasized the importance of sending messages to other family members. When asked whether she would want family messaging capability, PC7 replied, *"I would. Just to let them [children] know that somebody is watching and that it's [snacks] being documented for a reason [laughs] because you want to see how your family is eating."* PC4 thought messaging could

[1] PC[N]: Primary Caregiver[Participant Number]

be useful to remind children about healthy eating: *"I think it's a good idea, you know, because a lot of kids are obese in the country and sometimes if mom wanna send her [kids] a message onto her [kids'] cell phone in school or whatever to eat a healthy snack."* Secondary caregivers also found value in messaging since they felt it was important to help other siblings reach their snacking goals. Some secondary caregivers, however, were skeptical about the family messaging feature and said that the parents might get mad if they receive too many messages about healthy eating.

6.5.2.2 Snack Healthiness Representation

Of the snack health visualizations I implemented in the prototypes, the star representation of snack healthiness was well received by the primary caregivers. They identified it as a classical reward system: *"Maybe it's the childhood thing. We always got stars for doing well. And so ... As a token of appreciation and as a token to continue to do better... it's like a psychological imprint that's been put into our heads since I was little kid,"* PC4. While the secondary caregivers understood the star representations, they did not find it interesting.

6.5.2.3 Importance of Family Snacking Display

The primary caregivers believed that viewing the entire family's health was essential. PC7 said, *"It is helpful because if this [persona] was me and these were my children [laughs], I would be watching everything that they put in their mouths."* Similarly, PC8 said, *"I like the overall [family snack healthiness] average. You know it would prove a point that the whole family needs to eat better."* This is understandable since primary caregivers are the principle conduits for family health. On the contrary, secondary caregivers were generally more interested in individual health. PC4 wanted to view the details of what her family was eating: *"... when I want to go look at mine [snack history], I just want to be able to see my whatever [snacks consumed]. If I put my husband on a diet or he's trying to eat healthier, then I wanna be able to see that."*

6.5.2.4 Is Price Important?

While the primary caregivers favored most of the Snack Manager features, they thought displaying snack prices was irrelevant because snack healthiness was more important. When asked why she did not want prices, PC8 said, *"[Price shouldn't be there] because it really doesn't have anything to do with snacking."* Giving another reason, PC4 said, *"I think it shouldn't be ... because if this is going to be a nationwide thing, food really varies in every state ... it could be a discouragement for buying, you know fruits and vegetables."* Primary caregivers were not the only ones to criticize displaying snack prices, secondary caregivers also reverberated similar thoughts, SC16[2] said, *"It doesn't matter what the price is, if something is good for your body then you gotta pay for the price."* SC15 noted that snack prices could be discouraging if healthier snacks are expensive: *"They might see it and be like this one is, the healthy one is more expensive than what I am eating now so I can't afford so I won't."*

6.5.2.5 Secondary Caregivers and Management Interfaces

The secondary caregivers generally did not prefer Snack Manager because they found it *boring*. Unlike the primary caregivers, some secondary caregivers were skeptical about the family messaging feature and said that the parents might get *mad* if they receive too many messages about healthy eating. Others said that they might as well talk to their parent in person or show their snack healthiness on the phone application to encourage parents. The secondary caregivers preferred the multiple healthy snack suggestion feature, SC5 said, *"If it gives you to try apples or bananas instead of pretzels it is better, you got two choices. But if it says apples instead of pretzels but you don't like apples."*

6.5.2.6 Reminder Systems

While reviewing Snack Manager, one primary caregiver mentioned that a reminder system would be useful that reminded user about eating healthy, PC4 said, *"It kind of give you like a*

[2] SC[N]: Secondary Caregiver[Participant Number]

reminder because you know for people that are trying to eat healthy already struggle. That will be cool if your phone gives you a notification that it's time to eat a snack and a suggestion of what you should be eating because you can choose what your snacks should be and you can put that in there."

6.5.3 Lifespan

The Lifespan prototype was consistently preferred by both primary and secondary caregivers. Participants enjoyed the application's overall message of a healthy lifestyle. PC5 said it best: *"You prosper from healthy living ... your life expectancy might be as long and you can get all the things that you want cause you live longer to get it. That's how I see it ... it expresses more of how you are prospering with the way your lifestyle of eating and living."*

6.5.3.1 Motivation through Competition

Apart from the overall message of the application, the participants highlighted that Lifespan could be useful in encouraging healthy competition. Thinking aloud, PC4 elaborated, *"... it compares, you know, who has the highest points of healthy snacks. So she [user] might be upset if her brother is eating better than her or her sister ... she might wanna challenge herself to eat better ... I think adding the social aspect to it will [also] make it more stimulating for adults."* Similarly, PC3 mentioned, *"I like having the points because ... like a competition type of person wants points, like, wooo, I got five points, or oooh, I got ten points, instead of ... you ate 3000 calories."* While the primary caregivers identified competition as a useful motivator for their children, none of the secondary caregivers resonated with this idea. If we were to leverage a points-based system to encourage competition, we would have to avoid the use of negative numbers because a majority of the participants had trouble understanding them.

6.5.3.2 Game Character's Traits

Primary caregivers mentioned that the determination shown by the Lifespan character could be related to real life: *"If somebody was having health problems or was as determined as she [game character] is to get what she wants, they will probably use this one,"* PC1.

The secondary caregivers also corroborated on relating to the game character - SC5 said, *"... It's kind of like watching a video. It shows you emotions, what's happening, reactions, and everything."* SC5 further described how he could see people relating to the game character: *"I think she is wearing hijab and her name is Amna, she is Muslim. If you're Muslim you'll be able to relate to that."* SC9 also felt a connection with the character and described how he would eat healthy to make sure that the game character was successful in his life. Although most of the secondary caregivers preferred Lifespan, some complained that the game character was *too demanding* as she continued to ask the user to eat healthier snacks to get to the next level. The participants may have perceived the application as demanding because I accelerated the game progress to demonstrate the major game milestones within the user study. Normally, users would achieve these milestones over an extended period of time.

I also observed instances where the secondary caregivers extrapolated the game scenarios through their imagination. In one of the game stages, the character gets a job, on which SC8 said: *"By her eating healthy stuff it made her feel proud and now she's a teacher and she can probably teach her students."*

6.5.3.3 Social Network Gaming

Although the primary caregivers were not interested in a gaming application, PC4 said that playing a snack game with her friends on an online social networking website would be exciting: *"You can design it [Lifespan] a little further where you can put it on Facebook and where people can, ahh like, the Facebook friends make a little more challenging for them, and they could put their snacks in, and compare it with their friends. And at the end of the week, may be a week or two*

week to see whether they are losing their weight ... I think adding the social aspect to it will make it more stimulating for adult, you know, being able to do it with someone else."

6.5.4 Snack Educator

The Snack Educator prototype received mixed reviews from both primary and secondary caregivers.

6.5.4.1 Realistic Application

The participants described Snack Educator as *realistic* since it displayed implications of eating healthy or unhealthy snacks on their bodies. In PC8's words: *"It gives you a better understanding of what the consequences are."* I heard similar opinions from other primary caregivers. PC6 elaborated, *"... it gives you the difference. Like, the thing with the potato chips and then how bad it is for you and it does the comparison with oranges over here and sees how healthy they are for you. So that's very good."* Similarly, PC5 said, *"If they [people] use it [Snack Educator] to record their daily snacks, they would find out how healthy they are doing, their body is taking in with what they are feeding it and how much they are eating it everyday."*

The secondary caregivers also preferred the Snack Educator's realism as SC5 said, *"I think this one ... like it educates you more. It gives you the side effects. The ones [prototypes] we did before showed you unrealistic things. Like if you eat unhealthy, and some guy will take over the world [referring to Health Heroes]. That's not realistic."*

6.5.4.2 Differences over Health Metrics and Visualizations

Some primary caregivers showed concern over the Snack Educator visualizations that depicted potential obesity risk associated with a snack. PC3 said, *"If I see a fat person [Snack Educator image] next to me [in the application] and a skinny person next to Allison [example person], that makes me feel worse."* Some secondary caregivers also mirrored the same sentiment at the obese person's picture. When SC4 laughed at it, SC3 said, *"that's not funny, that's somebody's body, I*

would never make fun of it."

The primary caregivers were divided on visualizations of nutritional details. PC3 did not want to know the nutritional details or how the application calculated a snack's healthiness. She stated, *"I'm glad it didn't add calories. Like, that's a bad thing. I don't want to see the calories. So I like how they calculated to what's good and what's bad. I liked that. It wasn't like you had to add in how much you weigh and all that other embarrassing stuff. So I liked it was pretty self-explanatory. It was pretty simple to understand."* On the contrary, PC7 wanted to understand why a particular snack was healthy or unhealthy by tracking calories. When asked what would she modify in the application, PC7 replied, *"Ummm maybe the calories. So that way when you compare them, you can have this has this many calories and that has that many calories and, you know, that's why it would be a better snack."* Similarly PC1 also wanted to view nutritional details: *"No it is not useless cause one bag of chips might have more salt than the other ... I don't know if they are telling the truth. I want to see everything [nutritional]."*

6.5.4.3 Snack Healthiness Bar Interpretation

I observed that while evaluating the Snack Educator's family snacking screen (Figure 6.2c), the participants immediately identified Alice as eating healthier than Julia because the green portion of her bar was larger. The participants also noticed that Alice's healthiness bar was longer than Julia's bar because Alice ate more snacks. However, despite this observation, they still held the belief that Alice was eating healthier than Julia — neglecting snack quantity in their assessment. This ambiguity was intentionally designed to determine if users could account for quantity in snack healthiness evaluations.

6.5.5 Health Heroes

The Health Heroes prototype was not preferred by primary caregivers because they thought it was *childish* and difficult to understand. The primary caregivers could not relate to the Health Heroes game and did not find it motivating to adopt healthy behaviors. They further complained

that Health Heroes had cluttered action screens. PC7's feedback sums up the collective sentiment: *"Ummm, I didn't like that one [Health Heroes], it's a little funny looking. And it's for kids."*

6.5.5.1 Fun for Young Teenagers

While primary caregivers did not prefer Health Heroes, there was a split within the secondary caregivers. Mostly young males preferred Health Heroes because they thought the application was *cool* and found the game action exciting. For example, SC12 said, *"It's showing ... healthy people beating up unhealthy people. So that means you're starting to eat healthy and I kind of like it better. So I understand it, so I think that's why I like this one."* Similarly, when asked which was his favorite application, SC4 said, *"This one [Health Heroes] ... cause Taco Belly is kind of like a funny name and all of them [Health Heroes] work together to defeat him."*

The older teens, however found Health Heroes too childish for their liking. SC5 said, *"Like this would just make you think that you're a kid. I don't like that."* Another secondary caregiver mentioned that she wanted to view how food affected her body, SC8 said, *"I don't like this one [Health Heroes] as much as the first one [Snack Educator] because it doesn't really tell me how much I've grown and ... it didn't show the bar like the other one [Figure 6.2c]."*

In addition to issues discussed above, participants did not understand the overall progress of the game. Many participants did not understand the purpose and how to progress in the game despite a progress bar and an ambient home screen that updated according to the game progress.

I also used translucent overlaid help screens that appeared when the home screen was tapped. However, whenever these screen popped up, the users thought that they made a mistake using the application and suddenly wanted to close those screens.

6.6 Discussion

Given the prototype evaluation results that showed primary and secondary caregivers had different interface preferences, the challenge becomes to make technology accessible and useful to two different caregiver groups. Therefore, I explore how differences in primary and secondary

caregivers' preferences can be incorporated into an effective family-based application. I also discuss how a flexible health metrics tracking system can abstract nutritional details. Finally, I explore how individuals' sensitivities affect the application design and the importance of considering the holistic application message.

6.6.1 Management and Engagement

My results showed that the primary caregivers wanted an application that provided them with the ability to effectively manage their snacks. They had an intrinsic motivation to view and maintain healthy snacking for their entire family. They were not interested in spending time in gaming activities, that would serve as an extrinsic motivation to support snack management. This idea was highlighted by PC8 when she used Snack Educator after using the gaming applications, *"Ummm, it [Snack Educator] just seems to flow better. Didn't have too many graphics and it was straight to point."* Furthermore, the primary caregivers found the gaming applications childish.

In contrast, secondary caregivers found non-gaming applications monotonous and redundant as underscored by SC9 while using Snack Educator: *"It's lame because you have to go back and forth and [see] the same pictures over and over again."* SC10 continued, *"It's boring because you have to do this click and we have to just see who's getting healthy and who's not getting healthy like that."* This highlights that secondary caregivers want some form of engaging, fun interaction as an incentive in their snack management application.

I also found that while primary caregivers preferred the familiar stars as the reward mechanism, secondary caregivers were excited by the dynamic rewards that unfolded as they progressed through different stages of the game. Based on these findings, I suggest that applications be designed with (1) basic snack management features with familiar metaphors for primary caregivers, and (2) engaging game-like applications to encourage secondary caregivers' usage. The backend of these applications should be a common multimodal platform that tailors data for various front ends. This would allow for a family based solution that would accommodate both types of caregivers. Indeed, researchers have responded by developing backend architectures, such as Salud! [141] - a

common platform for consumer health applications. Using a similar platform, we can implement useful features such as messaging between family members to encourage healthy eating habits.

6.6.2 Healthiness Visualization Needs

During the study, I identified two types of health visualization needs, those for (1) uninformed health metrics and for (2) informed health metrics. An uniformed health metric was one where participants were not aware of how the particular metric affected their health, whereas participants were aware of the informed health metrics' effects.

In my study, I found that food quantity was an uninformed metric that the participants did not consider while deciding the healthiness of their snacks. This was evident in Snack Educator, where participants did not consider quantity when viewing the snack healthiness bar (Section 6.5.4.3). Indeed, research has shown that while the average portion size of snacks have remained relatively constant, the snacking frequency has increased significantly, resulting in an increase in the daily energy intake from snacks [103]. We need to address this issue by helping participants visualize the effects of snack quantity on an individual's health. I acknowledge that this is a challenging problem that requires an accurate measurement of a user's height, weight, and other health parameters, however, a good starting point could be categorizing healthy and unhealthy snacks with a predefined snack-entry threshold per day. For example, in a gaming application, if a user enters more than a predefined threshold for a particular snack, the application can deduct points to discourage overeating.

While it is important to educate users about how the uninformed metrics affect their health, I also identified informed health metrics where users provided feedback about their tracking preferences. For example, PC3 and PC7 had opposite views on tracking caloric intake, and PC1 wanted to track sodium in her snacks. While I acknowledge that the snack healthiness visualizations did not account for specific nutritional information, they were intuitive and could gradually move the user towards healthy eating. Moreover, a majority of the participants were satisfied with the abstracted healthiness representations and did not ask for nutritional information. If nutritional

details are needed, stars could be a good representation for each nutrient needed in the healthiness visualization.

6.6.3 Price: The Changing Requirement

Our prior studies have shown that low SES populations considered price an influential factor while making dietary decisions [110, 135]. I implemented price in Snack Manager to determine whether it was beneficial for the target population, but an overwhelming majority of the caregivers did not find it valuable. This change in requirements highlights a key aspect of the iterative user-centered design process where the users often reflect and reevaluate their design recommendations after viewing a particular implementation.

6.6.4 Designing for Sensitivity and Nurturing Health Values

We must design applications that are not only usable, but also are sensitive to the target population's needs. As highlighted in my findings (Section 6.5.4.2), some caregivers were sensitive to the obese person graphic in Snack Educator (Figure 6.2a). It made them aware of their own issues with obesity and body image. This is especially relevant for low SES populations since they are at a higher risk for obesity [5]. Therefore, if we are to induce healthy behavior change, our designs must accommodate for these perceptions of self-image. This may in turn increase adoption of health and wellness technologies in low SES populations.

Another important design consideration was the overall application message. The caregivers indicated how Lifespan propagated a hidden message of well being that would encourage them in using the application. In particular, the secondary caregivers related to Lifespan and inferred that healthy eating leads to successful life outcomes. This unanticipated result of *health as a value* [125] can be fostered to establish healthy lifestyles in secondary caregivers. Therefore, while researchers should have traditional design goals to motivate users to adopt healthy habits, we must also reflect on how the overall application message can nurture health values in the population.

6.6.5 Evaluating Gaming Applications

With the spread of mobile phones in the last decade, researchers have designed mobile phone games to encourage healthy eating in both children [167] and adults [90]. However, a fundamental question is, prior to long field trial, how can we evaluate these gaming applications in short usability testing sessions? For the evaluation of Lifespan, I wanted to provide the users a complete *feel* of the game, where they could experience how the game would unfold. Thus, I displayed all the major stages of the game in response to relatively fewer moves. However, some participants thought that the character was too demanding. Therefore, the researchers should find the right balance between providing the overall game experience and the game-progression rate so that the users while understanding the game dynamics can also play the game at an intuitive pace.

6.7 Conclusion

To address RQ3, I designed and evaluated four prototypes informed by different health behavior change theories. These prototypes provided users the ability to capture and view their own and their family's snacking habits. The four designs shared some basic snack management features such as recording and deleting snacks, viewing individual and family snack history. Two prototypes were non-gaming while the remaining two were gaming applications. The four prototypes were evaluated by eight primary caregivers and eighteen secondary caregivers where I found that while the primary caregivers preferred non-gaming, management-style interfaces, the secondary caregivers preferred the gaming prototypes. This raises an important design problem - how do we account for demographic-specific preferences in a single application. I also found that some caregivers were sensitive to either a particular type of visualization, such as an obese person graphic or a particular health metric such as calories. I suggest that designers of sociotechnical dietary interventions should develop interfaces that abstract away health information in visualizations that are meaningful and understandable to the target population. While accommodating for target users' sensitivities, these interfaces should also convey the potential positive and negative consequences

of healthy and unhealthy foods on users' health.

Chapter 7

Field Trial

Informed by the prototype evaluation study results, I developed a fully functional mobile phone application, Snack Buddy[1] that provided users with the ability to track and share their family snacking. The field trial was designed to address RQ4, RQ5, and RQ6, which were to understand how the users engaged with the application, and to evaluate its effect on their snack awareness and their short-term dietary behaviors. To answer these research questions, I evaluated the mobile phone snacking application in a twelve-week field trial with ten low SES families.

In this chapter, I first describe the final mobile application design and the application architecture in detail, followed by the field trial design and results. Finally, I present a discussion based on the results of the study.

7.1 Snack Buddy - Mobile Phone Application Design

The prototype evaluation study results showed that the participants had two distinct preferences about the prototype designs - primary caregivers wanted a snack management interface while the secondary caregivers preferred gaming mechanisms to encourage healthy snacking. I had two primary choices: either find a compromise and balance in a single design for both primary and secondary caregivers, or to provide both caregivers exactly what they wanted by designing separate interfaces powered by the same back-end. I decided to develop an application with two different front-end interfaces communicating with the same back-end because I wanted to provide both types

[1] Snack Buddy is the name of the mobile phone snacking application

of caregivers their preferred interaction based on prototype evaluation.

Therefore, the final application design for primary caregivers was informed by SCT while the secondary caregiver interfaces were informed by both SCT and the transportation theory. I used SCT because, for a family-based intervention, considering socio-structural facilitators is essential for a successful intervention [49]. Following, I discuss SCT based design elements in more detail.

According to SCT, it is important to promote self-efficacy by providing positive, vicarious experiences from which individuals can learn from others. In my application, I allowed family members to see each other's snacking habits and share their snacking experiences with each other. A simple example of these vicarious experiences is when a primary caregiver eats healthy, the secondary caregiver can view their parent's overall snack healthiness in the application. This can create a belief in the secondary caregiver that she could become healthy, which empowers them to adopt healthy snacking behaviors.

Another aspect of SCT implemented in the application was personal experiences where the users could view their personal snacking history, learn the areas where they were snacking poorly, and then try to improve their snacking. Finally, the application promoted self-efficacy by providing concrete, implementable steps in the form of healthier snack suggestions that the users could view, deliberate, and act upon.

As I found in the prototype evaluation study, the secondary caregivers wanted something more than the SCT motivators to engage in the application. Informed by the transportation theory, I designed the secondary caregiver interface to capture user's interest by an engaging, graphically rich multimedia narrative. The idea of the Lifespan game was to make users relate to a game character's life whose progress and success was based on the healthiness of snacks entered by the user.

In the prototype evaluation study, I mentioned that the Lifespan prototype design was informed by PAPM. However, in the final design of the application, I decided not to use it because while I was trying to create an immersive narration informed by the transportation theory, I did not want to limit the number of stages based on PAPM. Moreover, based on the prototype evaluation

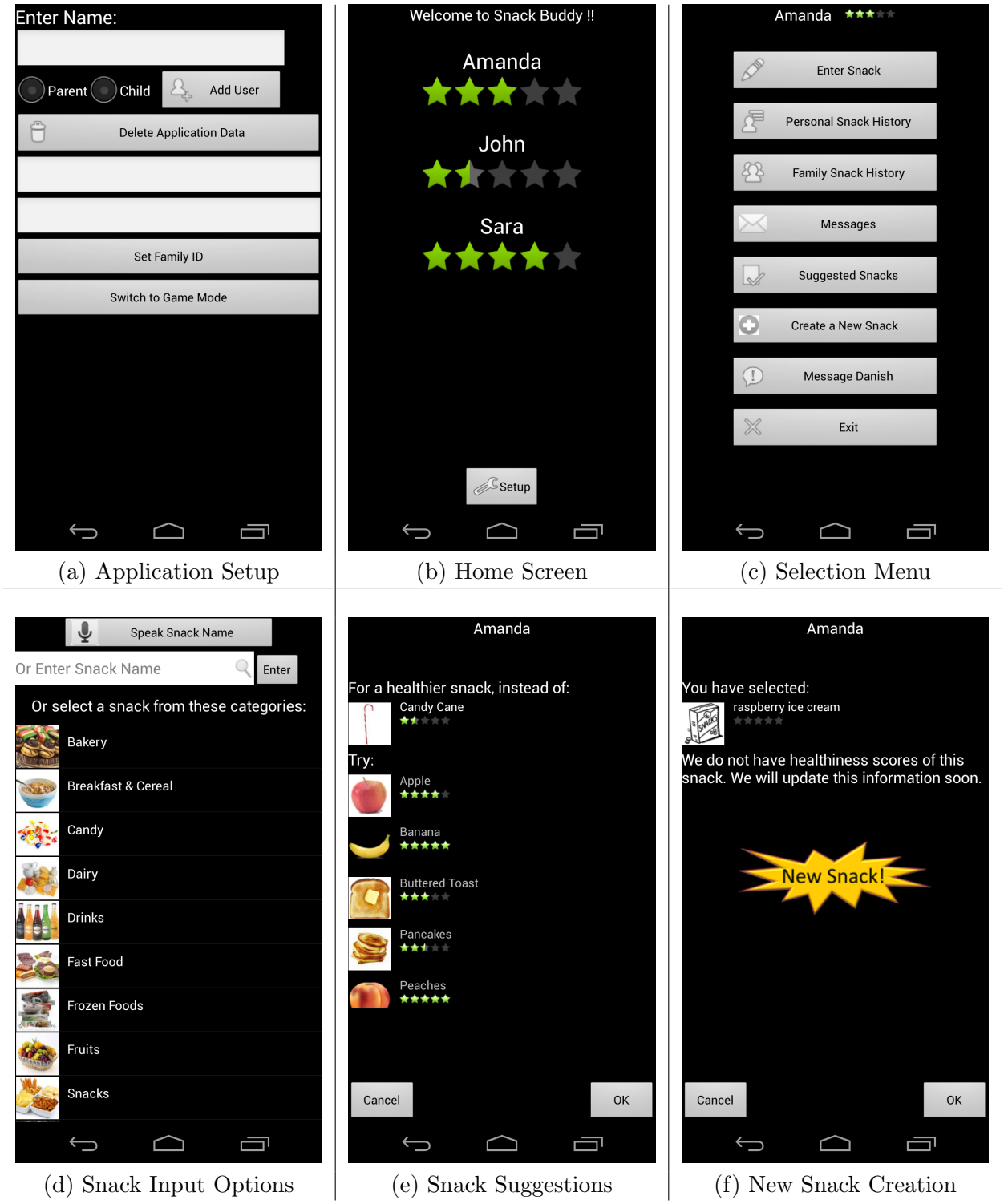
study results, I added goal-setting to the game design which compromised the PAPM framework. Finally, PAPM suggested that for an intervention, we first need to evaluate the current behavioral change stage of the user and then have them use the intervention from that stage. From the game's perspective, that translated to some players playing the game from the middle rather starting from the beginning, and this would have compromised the immersive narration that I wanted the users to experience.

7.1.1 Primary Caregiver Interface

The primary caregiver interface of the mobile phone application, Snack Buddy, was primarily informed by the Snack Manager prototype design evaluated in the prototyping study because this was the preferred interface by the primary caregivers. The setup screen shown in Figure 7.1a was used to add new family members to the application. Users could be added as a "Parent" or "Child." If a Parent user logged in to the application, she could view her child's snack history. However, a Child user could not view his/her parent's snack history. The setup screen also provided researchers with the ability to record multiple individuals as part of a family - this was the one-time initial setup that was required to identify which phones belonged to a single family. I used a passcode to restrict access to this feature, so only I could edit the changes in family identification. Users could also switch between the gaming and non-gaming interfaces on this setup screen.

Once the initial setup was done, the home screen shown in Figure 7.1b showed the average snack healthiness of each family member in star-based representation. The granularity of the healthiness rating was a half star. Once the user selected her profile from the home screen, Snack Buddy displayed a variety of options as shown in Figure 7.1c. Users could enter a snack, view personal snack history, view family snack healthiness, send messages to other family members, view a list of suggested snacks, create a new snack, and message researchers for any reason.

As shown in Figure 7.1d, Snack Buddy presented three different mechanisms to enter snacks: typing-in the snack name, speaking the snack name, or selecting the snack from a list of snacks. The typing was paired with type-ahead behavior where a drop down list appeared with predicted



(a) Application Setup (b) Home Screen (c) Selection Menu

(d) Snack Input Options (e) Snack Suggestions (f) New Snack Creation

Figure 7.1: Snack Buddy - primary caregiver interface setup and entering snack

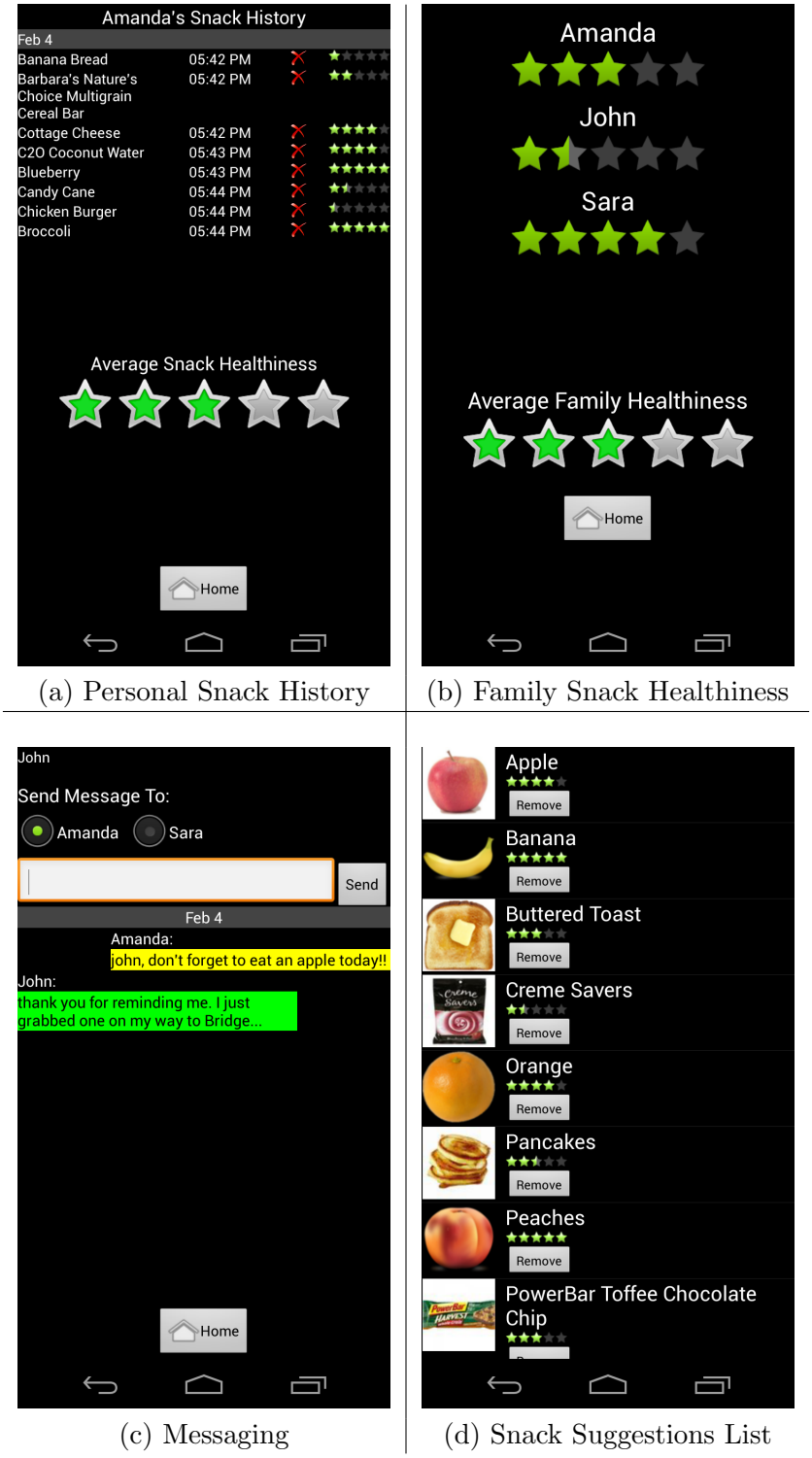
snack names along with their pictures. Voice input displayed all the possible words that Android voice recognition processed from user's speech. If there was a match between the possible words and predefined snacks, then an image would also appear next to the snack name. The users could also enter snacks by selecting from a predefined list of snacks that showed snack names, their pictures, and their healthiness rating in star-based representation.

If the snack selected by the user had a healthiness rating less than three stars, then users were shown healthier snacking alternatives as shown in Figure 7.1e. If the snack typed or spoken by the user was not present in the application, then Snack Buddy displayed a "new snack" icon (Figure 7.1f) along with a message indicating that the new snack healthiness rating would soon be updated. The new snack was reviewed and its healthiness score was updated by the researchers in the snack application monitoring tool. The tool updated the server-side database with the new snack information. Once updated, the new snack healthiness was broadcasted to all the clients through web service calls, the personal healthiness and family healthiness ratings were updated when new snack scores were received.

Users could also view their personal snack history, as shown in Figure 7.2a, that displayed snack names, their entry date and time, healthiness rating, and an option to delete the snacks if they were entered mistakenly. At the bottom of snack history screen, average snack healthiness of all the snacks was displayed. The family snack healthiness screen, shown in Figure 7.2b, displayed average snacking healthiness for all the users and average snack healthiness for the enter family. Snack Buddy also provided users with the ability to message their family members as shown in Figure 7.2c. When a new message was received, it was highlighted on the message selection button. Finally, as shown in Figure 7.2d, Snack Buddy presented users a list of all the snack suggestions that had been shown to them in the past. Users could also delete a suggestion from this list.

7.1.2 Secondary Caregiver Interface

The secondary caregiver interface was informed by the Lifespan prototype design evaluated in the prototyping study because this was the preferred design by the secondary caregivers. The



(a) Personal Snack History

(b) Family Snack Healthiness

(c) Messaging

(d) Snack Suggestions List

Figure 7.2: Snack Buddy - primary caregiver interface personal and family health tracking, messaging, and snack suggestions

Lifespan game provided users a game character whose progress in life was dependent on the healthiness of snacks entered in the application. The healthiness rating was presented in terms of health points because the secondary caregivers mentioned that continuously increasing points were more motivational than the stagnant five stars. The game was designed to encourage a healthy competition within a family where different family members had their own game characters, and users could see how their characters were doing against each other.

The game was implemented in a landscape design; when the users switched to the gaming interface, the phone automatically changed from portrait to landscape mode. The setup screen, as shown in Figure 7.3a, provided the same options as in the primary caregiver interface. After the users had selected a game character as shown in Figure(7.3b), they went through a small tutorial (Figure 7.3c) that showed game rules and objectives. The home screen, shown in Figure 7.3d, displayed the healthiness points of all the family members.

Based on the feedback from the prototype evaluation study, I implemented semi-goal-setting - the game had pre-defined major objectives, however within these objectives players could set their own goals. The major pre-defined objectives were to get a higher education degree, get a job, buy a car and a house, and then furnish that house. As shown in Figure 7.3e the players had the flexibility to select their goals for acquiring education; they could get a backpack, calculator, pencils, pens, notebooks, and a lunchbox in whatever order they preferred. Once the player had achieved a goal, it was highlighted in color as shown in Figure 7.3f.

On the menu options screen (Figure 7.4a), players could see their current health points, their current goal, and health points needed to achieve that goal. The menu options screen provided links to enter snacks, view snack history, view family snack status, messaging, suggested snacks list, create a new snack, and view game status. Similar to primary caregiver interface, the secondary caregiver interface (Figure 7.4b) also provided the functionality of text input, voice input, and list selection for entering snacks. If the player entered an unhealthy snack, their character appeared with a sad face and healthier snack suggestions were displayed at the bottom of snack feedback screen as shown in Figure 7.4c. The inclusion of negative character feedback was further justified

(a) Setup

(b) Game Character Selection

(c) Tutorial

(d) Home Screen

(e) Goal Selection

(f) Achieved Goal Highlighted

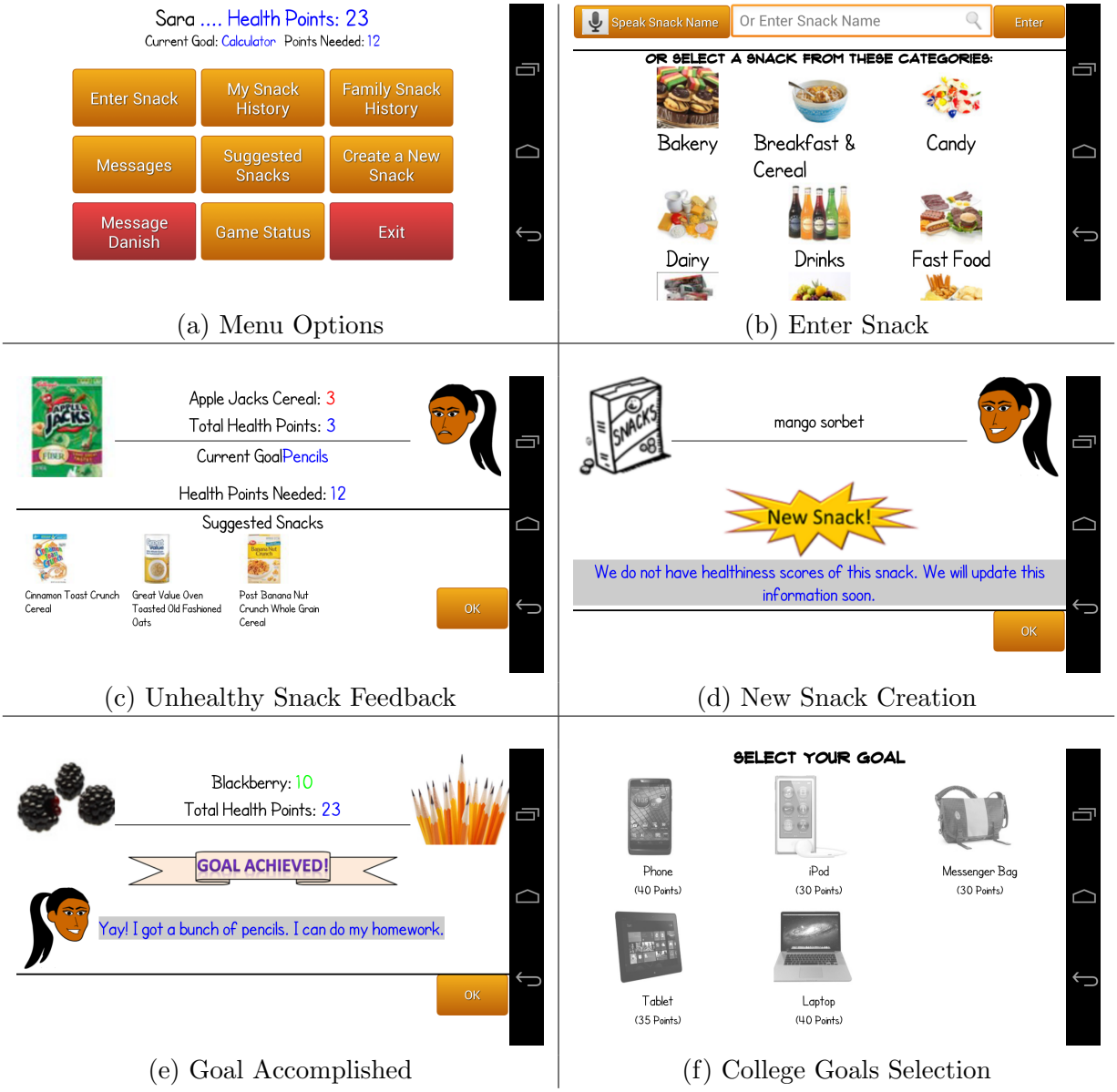
Figure 7.3: Snack Buddy - secondary caregiver interface setup and goal-setting

by [35] where researchers found that participants who received positive and negative feedback of a virtual character were twice as likely to eat breakfast than those who received only positive feedback. The snack healthiness points were displayed in red, yellow, and green colors for unhealthy, normal, and healthy snacks respectively.

When a user entered a snack that was not present in the application database, it would show a "New Snack!" icon (Figure 7.4d) with a message indicating that snack points would be updated soon. When users achieved goals, they were shown positive reinforcement messages as shown in Figure 7.4e. When users achieved all the goals in a major objective, they were shown an animation of the game character and newer goals for the next major objective were presented. For example, after the player completed the school, they advanced to college where they had to achieve goals shown in Figure 7.4f.

While most of the goals were selected by the user, some goals were pre-determined; for example, when a game character graduated from college, she would be assigned a pre-determined goal of finding a job as shown in Figure 7.5a. I used this approach because I did not want the game to always be predictable and monolithic. The idea was that these kind of subtle variations would keep the users engaged. The game also provided users with the ability to view their current game status that would show all the goals and major objectives achieved by the player as shown in Figure 7.5b.

Users could also view their detailed snack history (Figure 7.5c) that displayed snack names, their health points, and an option to delete that snack. I also displayed average healthiness of snacks in star-based representation because higher health points did not necessarily correspond to healthier snacks. Since there were no negative scoring, a user could accumulate health points by just eating lots of junk food. The average snack healthiness would then put things in perspective for the users where they could view how healthy their snacks were. The same star-based representation was also shown for each family member when viewing the family health status. As shown in Figure 7.5d, the family health status displayed the recent major objective achieved by each family member coupled with the star-based representation of the average healthiness of their snacks. The



(a) Menu Options

(b) Enter Snack

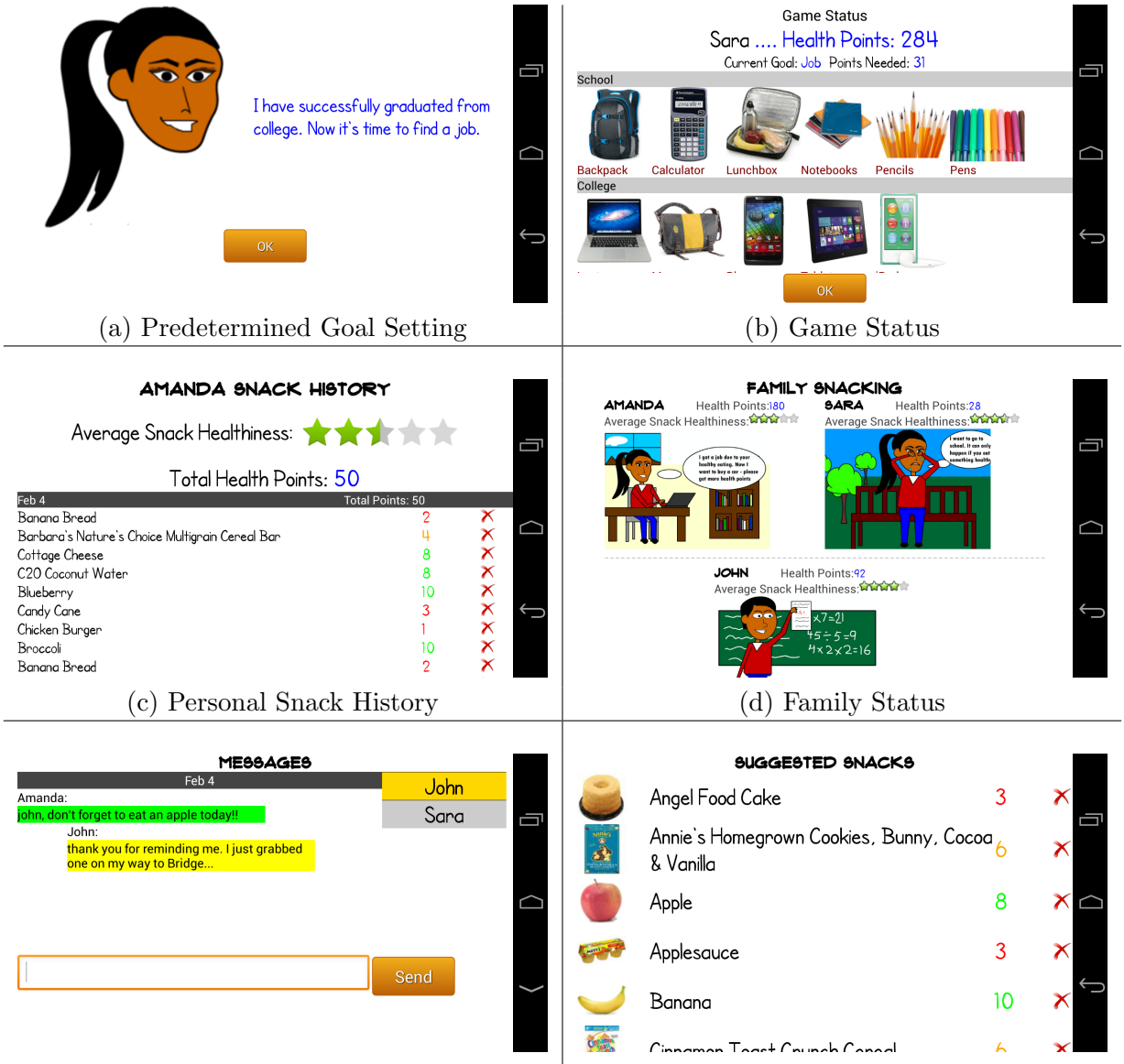
(c) Unhealthy Snack Feedback

(d) New Snack Creation

(e) Goal Accomplished

(f) College Goals Selection

Figure 7.4: Snack Buddy - secondary caregiver interface snack feedback



(a) Predetermined Goal Setting

(b) Game Status

(c) Personal Snack History

(d) Family Status

(e) Messaging

(f) Snack Suggestions List

Figure 7.5: Snack Buddy - secondary caregiver interface game status, personal and family health, and messaging

idea behind displaying the star-based representations was to provide a common ground to both primary and secondary caregivers to discuss their health progress in the application. Similar to primary caregiver interface, the secondary caregiver interface also provided the ability to send and receive messages to other family members as shown in Figure 7.5e. The application also provided a list of all the snack suggestions that the users had received in the past (Figure 7.5f).

7.2 Application Architecture

The application was developed using a typical client-server architecture as shown in Figure 7.6. In addition to these two components, I also developed another server-side application to monitor the real-time application usage, and update the snack database conveniently during the field trial.

7.2.1 Server

The server was hosted on a Mac Pro and consisted of PHP scripts (PHP version 5.3.1, API 20090626) that ran on an Apache 2 Web server (version 2.2.14). The server-side data was stored in a MySQL database (client API version 5.1.44) and the data was exposed using simple object access protocol (SOAP) web services.

7.2.2 Client

I developed the mobile phone application using the Android software development kit (SDK) API level 10 (version code: GINGERBREAD_MR1) that was supported by Android 2.3.3 and advanced platform versions. For development and testing purpose, I used the Samsung Galaxy Nexus touchscreen Android smartphones (GT-I9250) shown in Figure 7.7. I selected this phone because it was the latest Android Nexus phone at the time of development - the Nexus phones receive the fastest updates of Android operating systems from Google. I designed most of the interfaces using device independent pixels (DIPs). For client-side storage, I used SQLite database natively provided with the Android SDK. The mobile application could work off-line and synchronize data between

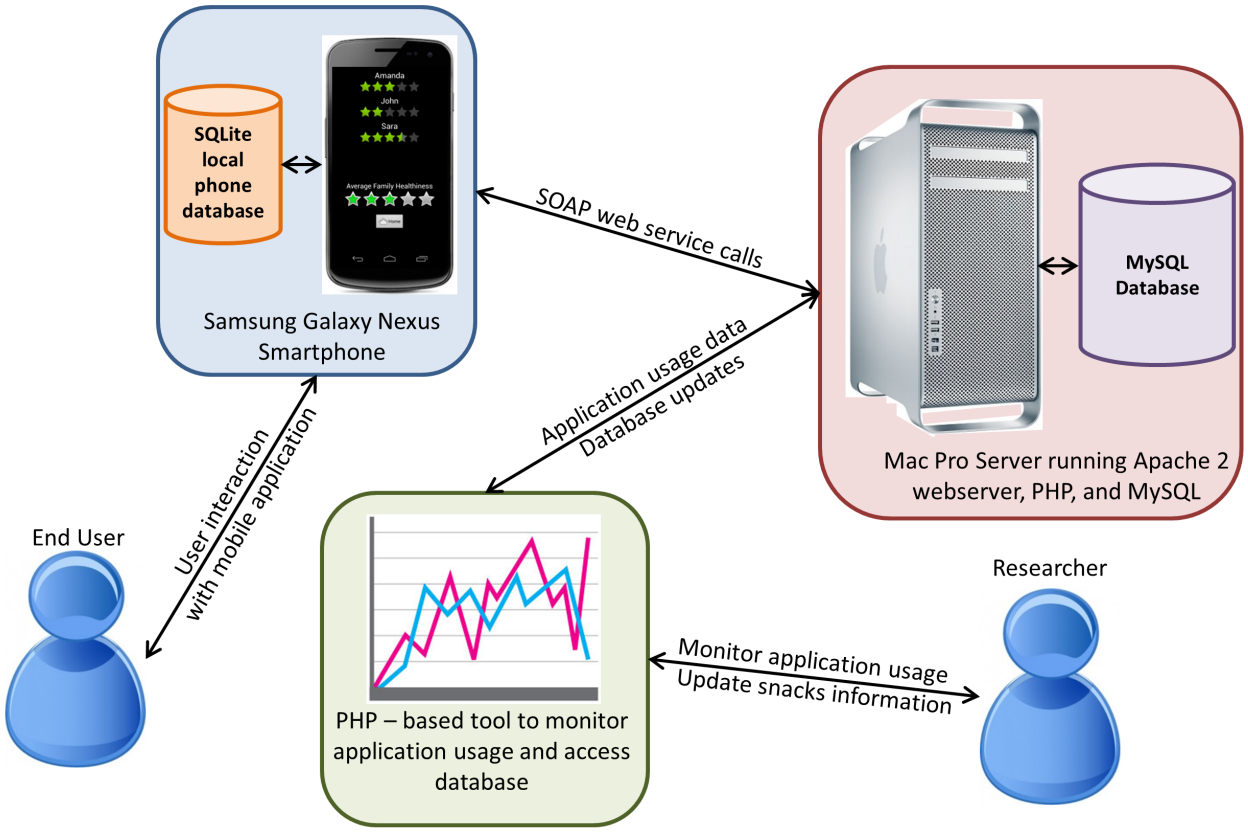


Figure 7.6: The Application Architecture

Figure 7.7: Samsung Galaxy Nexus smartphone running Snack Buddy in non-gaming interface

local and server-side databases whenever the Internet connection was available. I implemented the synchronization logic from scratch where I used the native mobile phone Unix epoch timestamps to detect and apply data modifications across the server and clients.

7.2.3 Server-side Monitoring Tool

The server-side monitoring tool, shown in Figure 7.8, was developed to analyze the real-time usage of mobile phone application by end users during the field trial. It showed researchers graphically the number of snacks entered by each participant, their healthiness rating, number of deleted snacks, and new snacks created by users per day. The monitoring tool also provided the ability to update the server-side database with new snacks which would then be broadcasted to all the clients. Additionally, researchers could view application usage summary, detailed screen by screen usage, received healthier snack suggestions, snack entry modes used, and messages sent to researcher by the participants. Access to the tool was password protected and participant names were anonymized to maintain privacy.

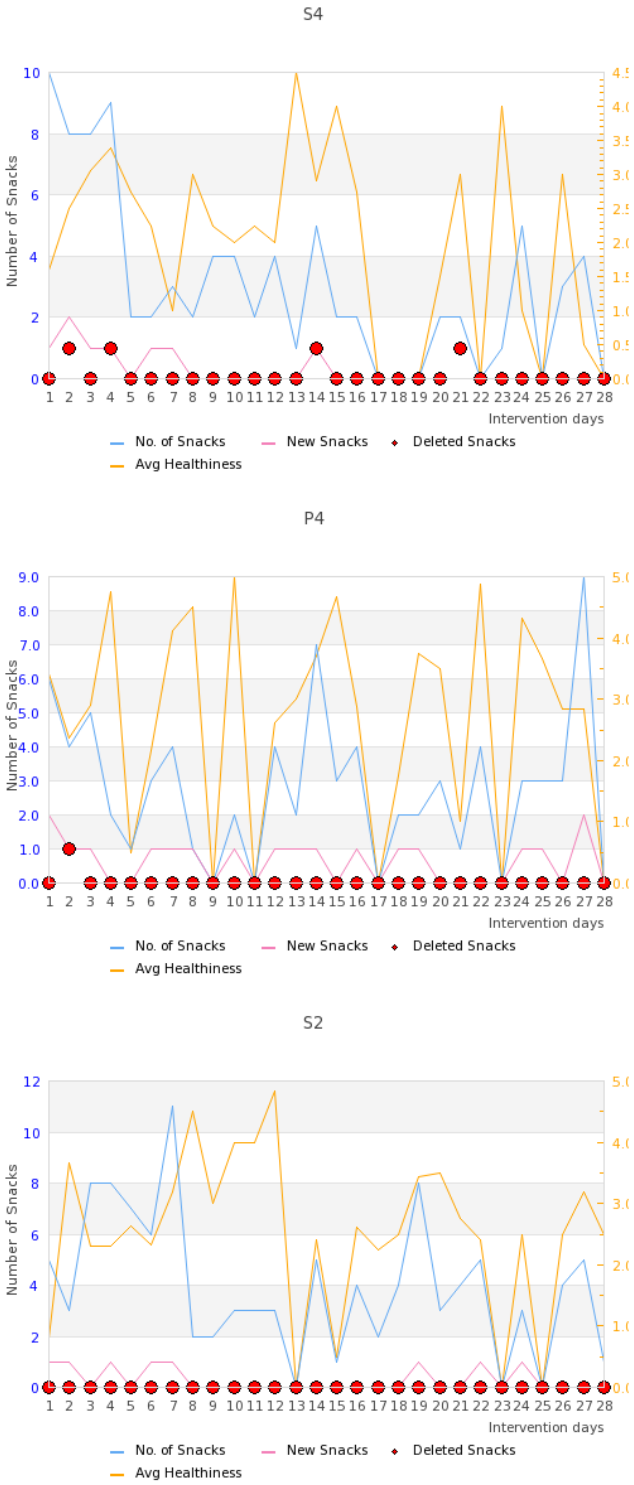


Figure 7.8: Server-side monitoring tool, real-time information plotting of number of snacks entered, number of new snacks created, number of deleted snacks, and average snack healthiness per day

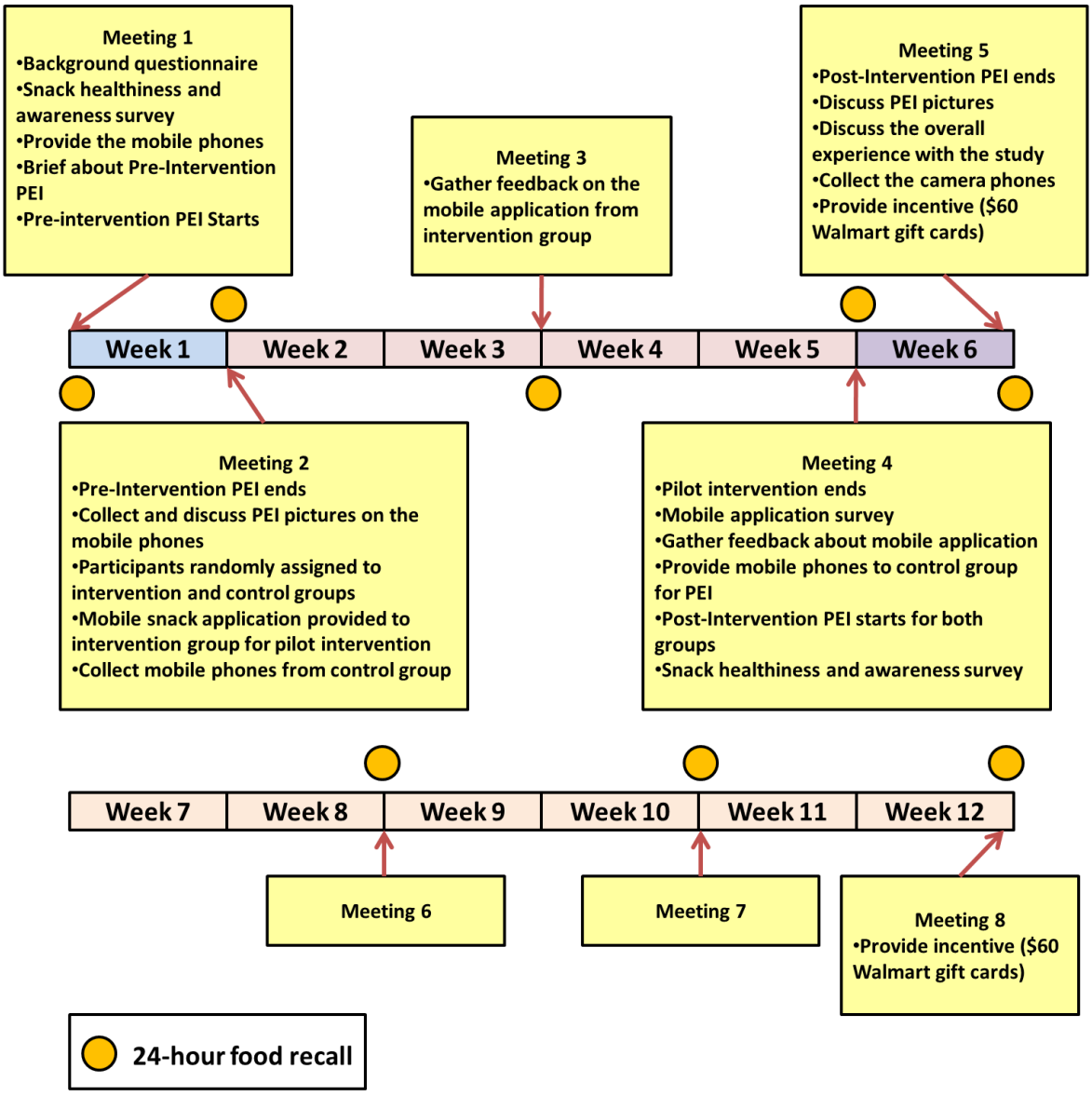


Figure 7.9: Field trial breakdown

7.3 Methods

Before providing the details about the actual field trial, I first discuss the in-house beta field trial that informed some changes to Snack Buddy design.

7.3.1 Beta Field Trial

Prior to starting the field trial, I conducted a one month long in-house beta field trial where I provided Snack Buddy to fellow researchers at my laboratory. After using it for one month, they identified snack input as a major problem because the application provided only a single input mechanism where users could select a snack from the predetermined snack list. Based on this finding, I added voice-input and type-in search mechanisms to Snack Buddy. The fellow researchers also mentioned that a user's current snack average healthiness in the non-gaming interface, and current total points in the gaming interface should be highlighted on the menu screen. I made these changes because it made users' current health status pervasively visible in the application, potentially making them more aware about their health.

7.3.2 Study Design

The field trial was a twelve-week long study with twenty participants from ten families; each family had a primary and a secondary caregiver participant. The field trial, as shown in Figure 7.9, consisted of eight meetings, that employed a variety of qualitative and quantitative methods designed to answer RQ4, RQ5, and RQ6. To address these three research questions, the families were equally divided into an intervention group and a control group; the intervention group participants used the mobile snack application for four weeks, while the control group did not use it.

To answer RQ4, which was to understand how users engage with the application, both individually and as a family, I analyzed the mobile application usage data, and conducted semi-structured interviews with the intervention group participants to explore their feedback regarding

the application.

RQ5 was how effective was my application at raising awareness of their own and their family's snacking habits? To answer RQ5, I designed a pre- and post-intervention snack healthiness and awareness survey questionnaire where I asked both the intervention and control groups to provide their perceptions about their own and their family's snack healthiness and awareness. These pre- and post-intervention questionnaire results were then compared for both intervention and control groups to examine how the application affected their awareness. I also explored the application's role in raising personal and family snacking habit awareness in the intervention group during the semi-structured interviews.

The last research question, RQ6 was to explore if the participants demonstrate any short-term dietary behavior change using the application. To address this question, I collected and analyzed dietary intake data for both intervention and control group using a pre- and post-intervention photo-elicitation interview (PEI) exercise, and eight 24-hour food recalls, where I compared the healthiness of their diet. During the pre- and post-intervention PEI, I asked the participants to take pictures of whatever they ate for duration of one week before the intervention phase, and one week after the intervention phase. Comparing the healthiness of pre- and post-intervention food pictures of both control and intervention groups highlighted if the application induced any short-term dietary behavior change.

I wanted to confirm the PEI results, and analyze the healthiness of participants' diet for a period of twelve weeks because this provided me with a trend of whether the participants' healthiness improved for a short span of time and then declined, or whether the participants adopted healthier eating behaviors and sustained them for twelve weeks. To explore this dietary trend, I used eight 24-hour food recalls that were conducted at different stages of the twelve-week study, where I asked the participants what they ate in last twenty-four hours. The 24-hour food recalls are highlighted by a yellow circle in Figure 7.9. I further examined the effect on intervention group participants' diet by analyzing the healthiness of foods they entered into the application. Finally, I also asked the intervention group participants if the application had any effect on their diet in the

semi-structured interviews. This quadrat approach to answer RQ6, involved PEIs, 24-hour food recalls, application and interview data that provided me a comprehensive understanding of the application's effect on the participants' diet. Next, I discuss the details of all the eight meetings of the field trial.

7.3.2.1 Meeting 1

After obtaining informed consent from the participants, they completed a background questionnaire (see Appendix F and G) where I collected information about basic demographics (age, gender, ethnicity, etc.) and their technology usage. The participants also completed a snack healthiness and awareness survey (see Appendix H) where I asked the participants about availability of fruits and vegetables in their house, their perceived consumption of fruits and vegetables, and their perception about healthiness of different types of snacks. I created this survey instrument to specifically assess participants' snacking behaviors and awareness. Although I was unable to identify a single instrument that assessed only the metrics that I was interested in, I based my questions surveys previously used by other researchers [124, 150]. I also conducted a 24-hour food recall (see Appendix I) where participants were asked about what food they ate in last 24 hours, and whether that food was a meal or a snack. I selected the 24-hour food recall because it is a validated food-survey instrument [133, 139] widely used in dietary and nutrition-related research [146, 192] to collect information on a participant's dietary intake.

The participants were then given a mobile phone, and were asked to take pictures of whatever they eat for one week. These pictures were for pre-intervention PEI. PEI is a widely used diary study method [28, 46, 47, 126, 159] where participants are asked to take pictures of specific objects or activities based on the research goal. Researchers then meet the participants to discuss these pictures to understand how they relate to their daily lives, exploring what the pictures represented and what was the context of taking the pictures. Since I used PEI to analyze the healthiness of their food, I did not explore the broad context of the pictures which is generally done in needs-assessment, rather I focused on what the foods were, and if they were cultural-specific foods, I

asked participants their ingredients so I could successfully rate its healthiness.

The intervention group participants were provided Samsung Galaxy Nexus phones because the mobile application was developed using these phones. I also wanted the participants to be comfortable using the phones and reduce the initial excitement that is associated with the novelty of a new device. Note that sometimes it is observed [189], that participants will use an application because of the novelty of the technology instead of the actual application. The control group participants were either provided a Motorola Droid phone or, if they preferred, they could take pictures with their own phones.

For the entire study, each participant was provided an incentive of $120 in the form of two $60 Walmart gift cards at the end of sixth week, and twelfth week of the study. This incentive was suggested by the Bridge Project personnel as it translated to $10 per week for the entire study. Initially we wanted to provide six $20 Walmart gift cards but the Bridge Personnel suggested it was not a good idea since it meant an increase in the number of meetings with the participants, which were difficult to arrange.

7.3.2.2 Meeting 2

I conducted the second meeting one week after the first meeting; I first discussed the pre-intervention PEI pictures with the participants. These interviews were video recorded with participants' consent. I also conducted another 24-hour food recall during this meeting. At this point, five families were placed in the intervention group while the remaining five in the control group. Initially, the participants were placed in the intervention or the control group by using a purposive sampling based on ethnicity, gender, and caregiver role (primary or secondary). However, while the purposive sampling based on gender and caregiver type was matched across the intervention and the control groups, I could not achieve a balance in ethnicities in both groups because of the limited recruitment pool at the two Bridge Project sites I coordinated with. I installed the Snack Buddy application on the mobile phones of intervention group participants and asked them to use the application for the next four weeks. The reason for selecting four-week period was that related

work shows that participants are initially motivated to use the system, however this *"wow factor"* decreases once the initial excitement about the device reduces. Siek et al. [189] found that dialysis patients lost interest in monitoring their nutrition intake within one to two weeks of using the PDA-based application because it did not provide feedback. In a follow-up study [51], they reported that a majority of participants used the nutrition monitoring intervention that provided feedback for six weeks. However some participants exhibited the wow factor which was clearly evident between the third and fourth week of usage. Therefore, a period of four weeks for my study will demonstrate whether the intervention engaged users.

The application was installed on the same phones (Samsung Galaxy Nexus) that were provided to them for the pre-intervention PEI. I also installed a SIM card on their phones which had a one-month unlimited talk, text, and data plan. I provided this plan because the application required Internet access and also if the participants wanted, they could use this phone as their primary phone. Finally, I performed the one-time application setup and showed the participants how to use the application. Unlike the intervention group participants, the control group participants did not have to use the mobile snack application, therefore I collected the mobile phones from them.

7.3.2.3 Meeting 3

The third meeting was conducted two weeks after the intervention-phase had started because I wanted to inquire if there were any small changes that the participants wanted in the application. In this meeting, I conducted a semi-structured interview with the intervention group participants where I discussed their feedback about the mobile phone application. The semi-structured interview questions were informed by the application usage trends of different participants. This meeting with the intervention group was video recorded to analyze participants' feedback on the application. As shown in Figure 7.9, I also conducted a 24-hour food recall with all the participants from both intervention and control groups.

7.3.2.4 Meeting 4

I conducted the fourth meeting four weeks after the intervention-phase had started, and five weeks into the study. In a semi-structured interview, the intervention group provided a comprehensive feedback about the application. In this interview, which was also video recorded, the participants discussed their likes and dislikes about the application and highlighted areas of improvement. The interview guide for meeting 4 is attached in the Appendix J. The intervention group participants also completed a mobile phone application questionnaire (see Appendix K) where I asked them different questions about their application feature preferences. Both intervention and control group participants were asked to take pictures of whatever they ate for one week as a part of the post-intervention PEI. The control group participants were provided mobile phones for taking the PEI pictures while the intervention group used the phones they already had for using the mobile phone application. I also conducted a 24-hour food recall with all the participants from both groups.

7.3.2.5 Meeting 5

The fifth meeting was conducted one week after the fourth meeting, and six weeks into the field trial. In this meeting, I discussed the post-PEI pictures with both intervention and control groups. The participants were also asked about their overall experience of participating in the study. I also asked the intervention group participants to compare taking food pictures with using the mobile phone application as an intervention. Both groups completed a 24-hour food recall. I collected all the mobile phones provided to both groups. A $60 Walmart gift card incentive was given to all the participants.

7.3.2.6 Meeting 6 and 7

After the intervention phase had ended, I monitored participants' eating habits for another six weeks by conducting three 24-hour food recalls two weeks apart from each other. Therefore, the sixth and seventh meeting each comprised of only a 24-hour food recall that was administered

either over the phone or as a text message based on participant's preference. Although I did not personally meet with the participants for these meetings, for consistency and easier understanding, I will refer to them as meetings. Meeting 6 and 7 were conducted eight and ten weeks into the field trial respectively.

7.3.2.7 Meeting 8

The final meeting of the field trial was conducted twelve weeks into the field trial. In this meeting the participants completed a 24-hour food recall and an incentive of $60 Walmart gift card was provided to each participant.

7.3.3 Participants

7.3.3.1 Participant Recruitment

I recruited twenty participants from ten families - a primary caregiver and a secondary caregiver from each family. The participant recruitment was facilitated by the Bridge Project personnel. I asked them for a purposive sampling of participants based on their gender, caregiver-role, and ethnicity, so they could be evenly placed in the intervention and control group. However, while the Bridge Project personnel were able to find similar gender and caregiver-role makeup for both the groups, they could not balance the participants' ethnicities across the groups because of the limited recruitment pool at the two Bridge Project sites. Although the study was twelve-week long, I could not run the study in parallel for all the twenty participants due to lack of participant-availability, limited resources, and logistics. Therefore, participants were recruited and the study was run in an ongoing, rolling basis from February to July of 2013.

7.3.3.2 Participant Demographics

The participant demographics are summarized in Table 7.1.

Control Group All the five primary caregivers in the control group were females and their average age was 43.4 years. Two primary caregivers identified themselves as Hispanic, two as White,

Table 7.1: Participant Demographics

	Control Group		**Intervention Group**	
	Primary Caregivers (N=5)	**Secondary Caregivers (N=5)**	**Primary Caregivers (N=5)**	**Secondary Caregivers (N=5)**
Age (mean, range)	43.4, 32-58	14.0, 13-18	40.4, 31-46	14.2, 13-15
Gender Female (N, %)	5, 100.0%	4, 80.0%	5, 100.0%	4, 80.0%
Ethnicity				
- Hispanic (N, %)	2, 40.0%	2, 40.0%	3, 60.0%	3, 60.0%
- White (N, %)	2, 40.0%	2, 40.0%	1, 20.0%	1, 20.0%
- Asian (N, %)	0, 0%	0, 0%	1, 20.0%	1, 20.0%
- African American (N, %)	1, 20.0%	1, 20.0%	0, 0%	0, 0%
Education				
- Graduate (N, %)	0, 0%	0, 0%	1, 20.0%	0, 0%
- College (N, %)	0, 0%	0, 0%	4, 80.0%	0, 0%
- High school (N, %)	3, 60.0%	1, 20.0%	0, 0%	3, 60.0%
- Middle school (N, %)	0, 0%	4, 80.0%	0, 0%	2, 40.0%
- None (N, %)	2, 40.0%	0, 0%	0, 0%	0, 0%
Work Status				
- Full-time (N, %)	1, 20.0%	0, 0%	2, 40.0%	0, 0%
- Part-time (N, %)	0, 0%	1, 20.0%	3, 60.0%	2, 40.0%
- None (N, %)	4, 80.0%	4, 80.0%	0, 0%	3, 60.0%
Has mobile phone (N, %)	4, 80.0%	4, 80.0%	5, 100.0%	2, 40.0%
Mobile phone experience				
- >5 years (N, %)	3, 60.0%	1, 20.0%	4, 80.0%	0, 0%
- 3-5 years (N, %)	0, 0%	2, 40.0%	1, 20.0%	2, 40.0%
- <3 years (N, %)	1, 20.0%	2, 40.0%	0, 0%	2, 40.0%
- None (N, %)	1, 20.0%	0, 0%	0, 0%	1, 20.0%
Has computer (N, %)	3, 60.0%	3, 60.0%	3, 60%	3, 60%
Computer experience				
- >5 years (N, %)	2, 40.0%	2, 40.0%	4, 80.0%	0, 0%
- 3-5 years (N, %)	0, 0%	1, 20.0%	1, 20.0%	3, 60.0%
- <3 years (N, %)	1, 20.0%	2, 40.0%	0, 0%	2, 40.0%
- None (N, %)	2, 40.0%	0, 0%	0, 0%	0, 0%

and one as African American. Three primary caregivers had a high school-level education, and two did not mention any education. One primary caregiver worked full-time, while the remaining four did not work. Four control group primary caregivers owned a mobile phone and used it regularly. Three primary caregivers had at least five years of experience of using a mobile phone, one primary caregiver had less than three years of experience using a mobile phone, and one did not have any experience with mobile phones. The primary caregivers used mobile phones for making/receiving calls, text messaging, and taking pictures.

Out of the five secondary caregivers in the control group, four were females and one was male; their mean age was fourteen years old. Two secondary caregivers were Hispanic, two were White, and one was African American. Four secondary caregivers were in middle school, and one was in high school. Only one secondary caregiver in the control group worked part-time. Four secondary caregivers had a mobile phone and three had at least three years of experience of using a mobile phone. The secondary caregivers made/received calls, text-messaged, and took pictures using the mobile phones.

Intervention Group The five intervention group primary caregivers were all females with an average age of 40.4 years. Three primary caregivers were Hispanic, one was White, and one was Asian. Four primary caregivers had some college-level education, and one had graduate-level education. Three primary caregivers worked part-time, while the remaining two worked full-time. All primary caregivers in the intervention group had mobile phones and had at least three years of experience working with them. The primary caregivers used mobile phones for making/receiving calls, text messaging, and taking pictures.

The intervention group secondary caregivers included four females and one male; their average age was 14.2 years. Three secondary caregivers were Hispanic, one was White, and one was Asian. Three seconday caregivers were in high school and two were in middle school. Two secondary caregivers worked part-time while the remaining did not work. Two secondary caregivers had a mobile phone and four had some experience of using mobile phones. The secondary caregivers made/received calls, text-messaged, and took pictures using the mobile phones.

7.4 Analysis

The data generated from the field trial included (i) pictures from the pre- and post- intervention PEIs; (ii) pre- and post- snack healthiness and awareness survey; (iii) 24-hour food recall data; (iv) participants' snacking information recorded by the mobile application; (v) usage patterns of the mobile phone application; and (vi) videos of the meetings.

I coded the PEI pictures for healthiness based on Fooducate database (fooducate.com), which provided a 0.5 to 5.0 scale for all food items and then used an analysis of variance (ANOVA) to examine between- and within-subject differences in food healthiness. For this analysis, I identified one significant outlier (>3SD), which was in the intervention group. I also used an ANOVA to examine between-subjects differences in the ratio of fruits and vegetables eaten versus the total number of food items eaten. For this analysis, two outliers were removed - one from each group (>3SD).

I analyzed the snack healthiness and awareness survey data by using paired T-test for differences between pre- and post-intervention survey for the intervention group. I used a one-way ANOVA to examine post questionnaire differences for snack healthiness and awareness between intervention and control groups, controlling for baseline survey responses. For the 24-hour food recall data, I rated the healthiness of all the food items using the Fooducate database, providing the same scale as the PEI. I averaged the healthiness of food eaten for each 24-hour period, and used a repeated-measures ANOVA to analyze if there were changes in food healthiness across the eight time points between the control and intervention groups.

Application usage patterns for the intervention group were analyzed by using SQL queries, PHP, and Excel graphs to identify trends in individuals and across participants. Videos from the semi-structured interviews with the intervention group in Meeting 3 and 4 were transcribed and coded using NVIVO 10 qualitative research software. I used grounded theory principles [4] to find emergent themes, which were discussed with fellow researchers to develop key findings.

7.5 Results

All the participants, including primary and secondary caregivers, preferred the application both after two weeks and after four weeks of usage. The participants said that the application made them aware of their eating habits, and educated them about alternative healthier snacks. Primary caregivers in particular appreciated the ability to track their family snacking where they could monitor what their children were eating. The participants also mentioned that the application promoted healthier eating habits; they enthusiastically discussed the application with their friends and colleagues. The secondary caregivers were motivated by the game and preferred competing against the primary caregivers of their respective families. I also found that although the application provided the ability to switch between the primary and secondary caregiver interfaces, both types of caregivers preferred the interface designed for their specific demographics. In this results section, all the participants numbered from one to five were in intervention group. PC[N] denotes Primary Caregiver[Participant Number] and SC[N] denotes Secondary Caregiver[Participant Number]; a PC and an SC having the same Participant Number were from same family, for example, PC1 and SC1 were from the same family, and PC4 and SC4 were from the same family.

Overall, the participants thought that the application made an improvement in their dietary habits and they provided several concrete examples of these cases. The following quote from PC4 sums up primary caregivers' thought: *"I like the application. I think it's a good way for people to choose a healthier snack, or just a way of eating or thinking what to eat."*(M4[2]). Similarly, the essence of secondary caregivers' feedback was summarized by SC2 when she said, *"I found it [mobile application] helpful cus like like every time I had to have a snack, it was organized and I put it in the app and it made me think about what I should eat, like, should I eat healthier?"*(M3). In the following sections, I first provide the quantitative feedback on the application using the post-intervention mobile application questionnaire, I then present detailed findings about participants' feedback on the application.

[2] M[N]: Meeting[Meeting Number]

7.5.1 Post-Intervention Mobile Application Questionnaire

The quantitative feedback on the application using the post-intervention survey (see Appendix K) suggested that the participants found the application easy to use, useful, and helpful in making them aware about their own and their family snacking habits. Nine of the ten participants reported the application was either very useful or useful on a five-point scale. Overall, the participants found that entering snacks, reviewing previous snacks, and getting the feedback on the entered snacks were the most useful features of the application. The participants did not find messaging or switching modes of much use although here I would briefly mention that nine out of ten participants switched the interfaces at least one time on their own.

7.5.2 Awareness about Eating Habits

All the participants mentioned that the application made them aware about their eating habits. An analysis of pre- and post-intervention snack healthiness and awareness questionnaire showed that there was no significant difference in personal snacking awareness, $t(9) = .612$, p = .555. However, the analysis revealed a difference in pre- and post-intervention family snack awareness that approached significance, $t(9) = 1.868$, p = .095. This suggests that Snack Buddy may have been effective in raising participants' awareness about the snacks that their families were eating. In the pre-intervention meeting (M1), participants in the intervention group reported being less aware of their family's snacking habits than their own, $t(9) = 2.70$, p = .024. After the intervention, this difference no longer existed $t(9) = 1.5$, p = .18. This further suggested that the application was effective at increasing each family's snacking awareness. Although I did not find a statistically significant difference in individuals' personal snacking awareness from the pre- and post-questionnaire, the participants provided details in the interviews about how the application made them aware of their own snacking habits.

Generally, this awareness was related to the amount of unhealthy food they ate. For example, PC2 said, *"Before this application I never realized how unhealthy our snacking was."*(M4). She also

said how realizing what she ate surprised her, *"I guess and then what's really really good about it is that you notice everything that you are putting into your mouth now and like: 'wow I eat all that?' ... and you see how much is unhealthy vs. healthy and you start kind of going that way: more healthy, more healthy, more healthy."*(M4).

Other participants also mentioned that they perceived their diet to be healthier than it actually was; for example, PC4 said, *"I was always trying to eat more healthier as I started using it. I mean, I was eating, I thought pretty healthy, but then I noticed I was eating candy and stuff that, you know ... Just exploring it, and using the app helped me."*(M4). PC1 also mentioned that the mobile application made her aware about the limited amount of vegetables she was eating, she said, *"Yeah I noticed I was eating a lot more like [pause] less vegetables, I noticed we weren't having vegetables and stuff, or I was eating too much candy going in there putting in candy. I'm going in there and like: 'I'm putting in candy again?' or you know I'm putting in a chocolate again."*(M4).

An interesting case was when PC5 realized that she was eating the same foods most of the time, she mentioned that she wanted to eat a variety of foods, *"It [Snack Buddy] helped me realize my gosh all this time I've been eating the same thing, and I don't want to eat the same thing, I want to eat a variety of things."*(M3).

During the study, I also found instances where other family members would remind participants about their snacks, and that would make them more aware about their eating habits. One such example was PC2 said, *"And usually, the one that just went in the kitchen [referring to child], he will be like, 'Mom you eat that, you eat that, you had this, you had that'. And I'm like okay, geez thanks. So it kind of makes them look and realize what you're eating."*(M3).

Similar to primary caregivers, the secondary caregivers also said that using Snack Buddy had made them aware about the snacks that they ate. Sometimes this awareness was related to the amount of food eaten, other times it was the healthiness of the dietary intake. For example, SC4 realized that she ate a lot: *"Well, I was always like, I don't eat a lot, but I do. I actually do eat a lot, and I do eat unhealthy. And so it made me realize I need to start eating better for myself."*(M4).

Most of the secondary caregivers mentioned that their realization of unhealthy eating habits was generally coupled with the notion of self-efficacy of being able to improve eating habits. For example, SC3[3] said, *"Whenever I have something that wasn't good, I was like: 'oh wow, okay I think I can improve this' "*(M4). SC5 mentioned instances where the application made her realize that she was eating too much: *"I looked through the history and I see all the lists of each day and I see how much I am eating per day. And I am like: 'oh I ate too much, I should have stopped eating and yeah'."*(M4). SC1 also became aware about his unhealthy snacks: *"[Using the application,] I found out that some of the snacks I had were unhealthy, and not good to eat."*(M4).

While most of the secondary caregivers discussed how the application made them aware about their poor eating habits, one secondary caregiver mentioned a trend from healthy eating to unhealthy eating; when I asked SC2 if anything surprised her about her eating habits, she said, *"That I can go from like really healthy to like junk food, but then like I start looking at the list and I think 'oh I should eat healthier'."*(M3).

7.5.2.1 Educate about Snack Healthiness

While the participants mentioned that the application made them aware about their eating habits, another important aspect of the application was that it educated the participants about healthiness of different snacks. PC4 said, *"I noticed I was trying to leave soda alone, and drinking a juice or finding something on there. I never used to drink my coffee black, and then now that I have seen that that is healthier for you I got a taste to drinking black coffee."*(M4).

Some primary caregivers also mentioned that the application educated them about healthiness of snacks that they were not sure about, for example, PC3 said, *"telling me the value of a certain snack, something you might not have known about a certain snack that might surprise you about the health value of it"*(M4). In other occasions, the participants found the application beneficial in conceptualizing the actual healthiness of a snack when they had a somewhat vague idea about it: *"I just knew like certain things that, cus that's why I have the almonds because I know that they're,*

[3] SC[N]: Secondary Caregiver[Participant Number]

they say that a handful a day is good, so I didn't know the health level, it just kind of tells me the things that I do eat, what the level is at."(PC3, M3).

Although some participants had a vague idea or were unsure about food healthiness, in some cases, the application helped to educate participants about their own false perceptions about food healthiness. For example, PC2 thought a chicken burger was much healthier than what the application showed it to be: *"Well I've realized that a chicken burger now, is not as healthy as I thought."*(M3).

Unlike the primary caregivers that often discussed learning the healthiness of different snacks, secondary caregivers provided lesser such examples. One example was SC2, who thought that hamburgers were as healthy as chicken burgers: *"I thought like a chicken burger and hamburger would be like the same thing because they are so worse, and then the chicken was higher [healthier]."*(M4).

7.5.3 Healthier Snack Suggestions

One of the main goals of the application was to provide healthier snack suggestions that could be used as an alternative to target population's current snacks. The primary caregivers found this feature very useful as PC2 mentioned, *"I really like it. It gives really good suggestions. Some really good alternatives."*(M3). Some participants just used the healthier snack suggestions to look up for an alternative snack rather than actually entering a snack; for example PC4 said, *"How it [mobile application] gives you the options: say you were going to choose a bag of chips, like it is giving you healthier snacks to choose. Then to think you know, I guess myself: should I really be eating this? Well, let me just enter it and see what it gives me, and I like that you can view that without hitting, unless you hit enter it would enter your snack, but you can just view and go along with it."*(M4).

The healthier snack suggestions were also preferred by the secondary caregivers. One secondary caregiver mentioned how the snack suggestions provide small, implementable steps towards healthy eating: *"So when I ate a hamburger and it suggested chicken burger. And then so when I ate the chicken burger, it suggested something else. So I was like, 'I have to keep going getting healthier.' "*(M4).

SC1, who regularly played football, recalled that Snack Buddy provided him a useful suggestion of replacing his sports drink: *"With the suggested snacks part of the app, it showed me some healthier snacks, like when I had a Gatorade, it showed MIO [another sports drink] as the healthier choice."*(M4). The application log data showed that SC1 recorded MIO two times after the suggestion. This change from gatorade to MIO was a single, implementable change that SC1 felt was possible for him to undertake and again underlines the importance of providing specific suggestions and feedback.

7.5.4 Tracking Family Health

Snack Buddy provided the primary caregivers with the ability to view what their children ate. This was one of the most preferred features among the primary caregivers and they found it useful in multiple ways; it made them aware about what their children ate throughout the day, it promoted family discussion on health habits, it provided them a starting point for meal-planning, and finally, it also made them reflect about serious chronic health issues, such as obesity.

Consider PC2, who had six children and worked full-time. In her busy schedule, she always found it difficult to stay informed about what her children were eating in her absence. However, she found the tracking family health feature very useful as she said, *"... looking at their (kids') snacks and looking at the stuff on the application and thinking: 'well gee, they could have this instead of that' and you know. It kind of helped me monitor I guess, what the other kids were eating."*(M4).

The tracking family health feature provided the primary caregivers, a sense of comfort because they were unable to necessarily see what their children were eating throughout the day otherwise, this was a unique stream of information that they were not privy to without the application. For example, PC3 mentioned how useful it was to be able to track her daughter's health: *"I tend to go on there [family snack tracking] either every day or every other day, I go and I just see what she's putting down as her snacks ... it helps me to know what she's [referring to daughter] eating for snacks. I know when she usually goes to Boys and Girls club she tends to have a good snack, but like if I'm working and she's home during, on the weekends then I know what she's getting*

because it will come up and show me her food choices while I'm at work."(M3). PC1 mentioned that she "enjoyed" viewing her son's eating habits: *"I can't always, I don't always know what he is eating throughout the day. I only know what he is having when he is with me, and see in that, he is willingly putting in what he is eating. So yeah I enjoy that, I like that."*(M4).

I also found cases where the family health tracking could have instigated the idea of meal-planning in primary caregivers. For example, PC4 was a mother of four who also worked full-time; she mentioned that the awareness of her children's eating habits could motivate her to plan meals in advance to make sure they were eating healthy foods, *"It is useful because then I can view my kid's snacks. If they are not eating healthy at school or, view what they are putting in: because maybe then I can have something planned out where they make sure they go to school with something I know they are going to eat."*(M4).

Interestingly, some primary caregivers thought that family health tracking could be useful in mitigating some serious chronic health issues such as the obesity epidemic; this was highlighted by PC3: *"it helps parents really monitor and try to help their kids stay away from the obesity or get away from the obesity issues."*(PC3, M4). PC3 mentioned how viewing family healthiness was useful to her, *"Yeah: definitely it [improves family healthiness]. Because if I wanted, I could see our average family healthiness and then I can go to the individual. Like my daughter, I can go to her personal rating with healthiness out of the maximum. And if I needed to go through and look at the kind of things she is eating, specifically which things and give me more of an idea."*(M4).

Unlike primary caregivers, Snack Buddy did not provide the ability to secondary caregivers to view their parent's detailed snacking habits. This was a deliberate design decision because I did not want to unsettle the conventional power-dynamics in a household. Therefore, the secondary caregiver's feedback on family health was generally related to game-points-based healthy competition within the family as shown in the following section.

7.5.5 Promoting Healthy Competition within the Family

Snack Buddy promoted healthy competition within families by providing users with the ability to compare the healthiness of snacks of different family members. I expected the competition-related feedback to be more from the secondary caregivers, however I found that even primary caregivers also mentioned how the application promoted a health competition. For example, PC1 said, *"There was like a little friendly competition I guess."*(M3). Similarly, PC3 said, *"Um, sometimes it's like a competition, it seems like who's higher ... cus my phone shows that she's got more stars, but on her application, I've got more points. So ... um, and she can watch and she's like you're ahead of me! So I think it's kind of like a, a healthy competition going on."*(M3). PC3 and SC3 discussed how they would consistently be checking up on each other to see how they were doing in comparison, which would sometimes flow over into real life, when they would discuss their competition in person. Both PC3 and SC3 discussed the competition in a wholly positive manner, and did not raise any concerns about negative competitive experiences. Interestingly, as a family, they showed the highest collective increase in family snacking awareness in the intervention group.

The secondary caregivers were very excited about the competition aspect of Snack Buddy. They said that the application was a healthy competition, and it was always fun to compete agains their mom. For example, when I asked SC3 which interface she preferred, she said, *"I prefer the game one."*, I asked why? She said, *"Because I like the points in it, and battling with my mom."*(M3). She continued how the competition kept her motivated: *"I think it helps motivate me to have more healthier snacks, click on game mode, go to hers and say 'oh, dang mom, you're ahead of me'. Dang girl, you're ahead of me."*(M3).

During the field trial, only primary and secondary caregivers were using Snack Buddy. However, since secondary caregivers had many siblings who could potentially use the application, I asked the secondary caregivers about what they thought of having their siblings using the application, and competing against them. They said the competition would be more intense, for example, SC5 said, *"Yeah I think [I would compete] more so than with my mom."*(M4). SC2 also mentioned that

she always competed with her siblings, so competing with them using Snack Buddy would be more fun. Most of the secondary caregivers had siblings, so this extension was logical for them. Even primary caregivers felt that facilitating competition within their children would be helpful, not just for their health, but also in bringing them closer together by enabling interactions throughout the day.

7.5.6 Inducing Healthy Behaviors

One of my main goals for designing Snack Buddy was to induce healthy eating habits in the target population. After the end of the intervention period, during the post-intervention PEI (Week 6), our analysis revealed a significant difference in the overall food healthiness reported in the PEI between the control and the intervention groups, controlling for pre-intervention PEI food healthiness, $F(1,16) = 4.62$, p = .047. Participants in the intervention group increased their average snack healthiness (M=.47, SD=.18) by over twice as much as the control group (M=.22, SD=.30). In addition, there was also a significant difference between the two groups in the ratio of fruits eaten to total food items reported in the post-study PEI, controlling for the ratio in the pre-intervention PEI, $F(1,17) = 4.89$, p = .041. On average, the intervention group increased their ratio of fruits to the rest of their diet by 7% while the control group remained stagnant. However, there was no difference between the two groups in the ratio of vegetables in their diet, $F(1,17) = .89$, p = .359. This analysis demonstrates a significant effect of my intervention on both the overall healthiness of foods eaten by the participants and the amount of fruits in their diet.

While the PEI results highlight the immediate effect of the intervention, the 24-hour food recall analysis demonstrate a sustained change during the six weeks immediately following the intervention. As shown in Figure 7.10, the intervention group participants showed a statistically significant difference in the healthiness of their diet over time compared to the control group participants. This average healthiness was based on the eight 24-hour food recalls per participant conducted throughout the twelve-week span of the entire study. A two-way repeated measures ANOVA revealed a significant interaction between the study week and the experimental condition

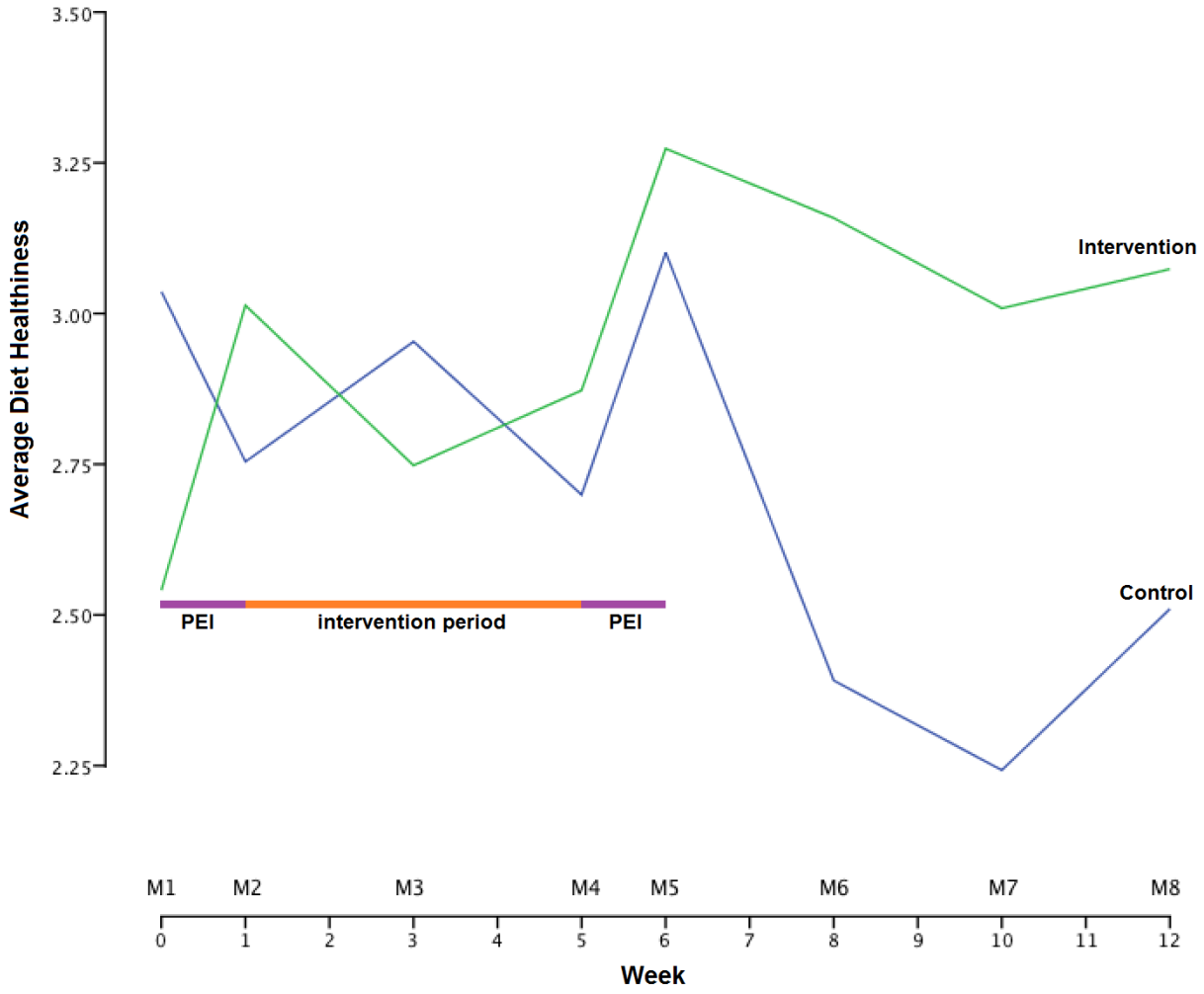


Figure 7.10: Average 24-hour food recall healthiness over twelve-week field trial; M[N]=Nth Meeting when a 24-hour food recall was conducted; The healthiness ratings range from 0.5 to 5.0, the graph is zoomed-in to highlight the statistically significant difference between the control and the intervention groups

(control versus intervention), $F(7,126)=2.91$, p=.007. This interaction suggests a difference in the healthiness of the food reported on their 24-hour food recalls differed between the two groups over the course of the study. The graph, shown in Figure 7.10, displays the nature of this difference; as the study progressed, participants using the intervention reported eating healthier foods than those in the control group.

These patterns were further confirmed by all the participants in the intervention group who mentioned that the application had improved their eating habits. Many primary caregivers gave concrete examples of dietary change, for example, PC2 said, *"And then it also helped to umm, change my snacks. Like rather than a bag of chips, I'll have some almonds or a banana or something. It's healthy, it's helping me to make healthier choices."*(M3). This was not limited to Meeting 3, PC2 noted similar observations in Meeting 4: *"my weakness was candy, you know using the application I was starting to think that I shouldn't be eating this stuff."*(M4). Similarly, PC4 observed how the application was beneficial to her in reducing candies: *"My big thing is chocolate candy, I'm all [gestures eating lots of candy] I'm breaking out from it. After a while I leave it along though. It [Snack Buddy] helps, it helps to give me that choice of an apple or a banana."*(M3). In a later meeting, she further mentioned about moving towards healthier eating habits, PC4 said, *"I noticed as I've been [using this application], I have been eating a lot more salads. I'm getting back into my routine of trying to watch what I eat."*(M4).

Some primary caregivers mentioned that using the application had broadened their healthier snack choices. PC4 mentioned how she had started noticing healthy foods: *"I notice I cut down on candy and I'm trying to choose healthier [foods], you know, I browsed it [application snack list], looked at all the snacks, looked at some of the food I don't usually buy."*(M3). Somewhat along the same lines, PC5 highlighted how she realized to eat different types of foods: *"It [Snack Buddy] helps me realize, you know, my gosh, often times I have been eating the same thing. I don't want to eat the same thing. I want to eat a variety of things. So I actually have learned to eat different things. Since you know I joined this study."*(M4).

The effects of using Snack Buddy were not limited to just dietary habits, one participant

to my surprise mentioned that the application caused her children to reduce their weight: *"Alex*[4] *and Jordan*[4]*, my two youngest were getting really heavy there, and now that we are monitoring the snacks, Alex has lost a lot of weight, and my son is starting to go [in that direction] as well. So yeah it is very helpful ..."*(M4). In some cases the mobile application also affected cooking and meal preparation: *"before I joined the study, 90% of the time I don't cook. So but, now since I joined the study I try to cook more at home and not eat out all the time."*(PC2, M4). Similarly, PC5 noted how her family reduced eating out: *"Because in my house I don't buy junk food. I mean we do eat out but we ... these few months when have been eating a lot less out. Before, we used to eat out every day which is really bad. Like my daughter said now she brings food to work."*(M3).

Working with this population, I had found that "Hot Cheetos" was one of the most preferred snacks of the secondary caregivers. I was glad to know that the use of Snack Buddy reduced Hot Cheetos consumption in at least one case as highlighted by PC3: *"before we started [using this application] she [SC3] would always eat the Spicy Cheetos or whatever ... with lunch of something, so I don't think she's really doing that now."*(M4). Confirming PC3's comment about SC3, SC3 mentioned how she reduced Hot Cheetos and replaced it with fruits, she said, *"Like if I was eating like Hot Cheetos that's not really healthy."*, I followed up by asking her what would she eat instead of Hot Cheetos? SC3 replied, *"I would eat strawberries or any kind of fruit or vegetable."*(M4). The application log data showed that all the secondary caregivers except SC3, had at least once recorded Hot Cheetos or Cheetos which confirms how Snack Buddy helped SC3 in making healthy snack choices.

While most primary caregivers told me how the application was useful to them, some also mentioned that Snack Buddy had improved health habits of family members that were not using the application; PC2 cited this change in her grandson: *"My grandson, I didn't realize he was having unhealthy snacks either. So now we have gotten to the habit where we look at everything, like sugar content and stuff like that ..."*(M4). It is important to note here that PC2 lived in a house with her six children and several other family members, so it was possible for the application's effects to

[4] Name has been changed to maintain privacy

spread beyond those that were actually using it. The other members of the family would get to see the application and its recommendations, which became part of the family's process in selecting and preparing food. In effect, it became a tool for the entire family, not just the users.

During the interviews, the secondary caregivers also mentioned that Snack Buddy had helped them move towards healthy eating. The secondary caregivers provided many concrete examples where they reduced unhealthy foods and increased the healthier alternatives. SC2 provided multiple examples: *"I haven't had chips, I had chips today, but I usually replace it with grapes. I mean, not grapes, but oranges. That's why if you look at my thing [snack history in the application], there's oranges on it a lot."*(M3). In the following meeting, SC2 reiterated on this fact: *"I tried to like eat less of chips and all and starting eating fruits and vegetables and I slowed down on my soda drinking a lot."*(M4).

While most secondary caregivers discussed how Snack Buddy assisted them in improving health habits when they were using the application, one secondary caregiver mentioned that not using the application for some time made her eating unhealthy; SC2 said, *"I was going back down and then I realized just because I am not using the app any more doesn't mean I can stop eating healthy."*(M4).

There were also other examples where participants reported an increase in fruits: *"I eat the same amount of what I have been eating, but I eat some fruits too to go with that."*(SC5, M4). SC5 also mentioned how reducing "junk food" affected her friends eating her food: *"I bring dinner there [work] because I stay there late so I eat there and I usually bring junk food and so my friends would share it with me because they liked that, but lately I have been bringing fruits and all that healthy stuff and they wouldn't even touch my food."*(M4).

7.5.7 Discussing Snack Buddy with Friends

During the interviews, I also explored the participants' perceptions about using the application at their work place or at school; I was interested in understanding whether the participants shared any information about the application with their colleagues and friends. I found that most

of the participants discussed Snack Buddy with their colleagues and friends. The primary caregivers mentioned that their colleagues wanted the application once they were told how it worked. For example, PC4 said, *"I talk to my co-workers a lot about the app. They were like: 'why are you taking pictures of your food?' and then I started explaining and they were like very interested and saying how neat that was and if that was available to them they would probably use it."*(M4). Similarly, PC2 also mentioned how her friends were interested in the application: *"I have like friends at work, and just regular friends: 'What is that app? I want that! I want that!' "*(M4).

The primary caregivers did not seem to have any privacy concerns about using the application in front of their colleagues; PC1 said that she regularly used it in front of her colleagues during the study: *"I would tell them about it, and they would see me taking pictures of food, or punching it in, and I would tell them what it was about, and explain it to them."*(M4).

The secondary caregivers, perhaps even more so than the primary caregivers, were extremely interested in showing the application to their friends. They told how their friends reacted after seeing the application, SC2's friends asked if they could have the application: *"When I got the app they were like: 'oh so it's this now?' and I was like: 'it keeps track of what I eat throughout the day and it suggests better snacks for me' and they are like: 'oh cool' and like my friends wanted to use it but I don't know if it's an app yet [if it's available to public]."*(M4). I also observed another case where the friend of a secondary caregiver asked whether the application was available online for public access: *"I showed my friend the app and he liked it and he asked me if it was on the Google Play and I was like: 'no, not yet!' "*(PC1, M4).

SC4 also explained that her friends showed a keen interest in the application and wanted to learn how to use it: *"Yeah, I did show them the application and they said it was really cool and they were like: 'well how do you do it?' and I just told them you entered in a snack and it gives you points. And they were like: 'so it's a game?' and I'm like yeah and so they really liked it."*(M4).

While most seconday caregivers talked about discussing the application with their friends, SC4 mentioned that she told her grandmother about the application, who would then remind her to enter the snacks: *"Yeah I would, like you know, my grandma would tell me: 'you need to put*

this snack in' or 'what have you eaten today? Have you put it in?' You know she really liked the application too and she thought it was a really neat thing to do. Just to have."(M4).

7.5.8 Switching the Interface

Since participants could switch between the primary and secondary caregiver interfaces, I asked the participants if they switched to experience the other interface. I found that both primary and secondary caregivers generally stuck to the portion of the application designed for them: parents to the parent interface and teenagers to the gaming interface. The primary caregivers were not interested in gaming, for example, in Meeting 3, after using the application for two weeks, PC2 said, *"I didn't use the game because I don't know how to do games. I'm lucky I know how to use the phone."* When I asked the same question in meeting 4, PC2 again said, *"Now the game I had no clue."* For most primary caregivers, they perceived the game interface to be more complicated, which discouraged them from using it. Parents felt less confident with using the technology and therefore opted to use the interface that they felt was easiest. Primary caregivers PC2, PC4, and PC5 - all mentioned that their inexperience with smartphones or lack of confidence in using technology prevented them from switching interfaces, this was despite PC4 and PC5 having a smartphone.

In addition, all the primary caregivers said that they were satisfied with their interface which contributed to them not paying much attention to the gaming interface, PC1 said in Meeting 4: *"Yeah I didn't do the game one. I just did the parent one. That was fine. I liked seeing the stars, and be like 'oh, okay I'm doing a good job'. This is alright if I had 3 stars or 4 stars, I was like 'doing good'."* PC4 also mentioned how she just preferred the parent interface: *"I didn't [use the gaming interface]. I did switch over and kind of looked at it, but I didn't mess with it. I preferred the regular [parent interface]."*(M4).

Some primary caregivers were just curious and explored the gaming mode but did not play the game as highlighted by PC3: *"You know, I hadn't really tried actually doing anything during the game mode, I just went to it to look at it, but I haven't tried using the game mode. But I don't*

mind the stars. I know she [SC3] likes the game mode."(M3).

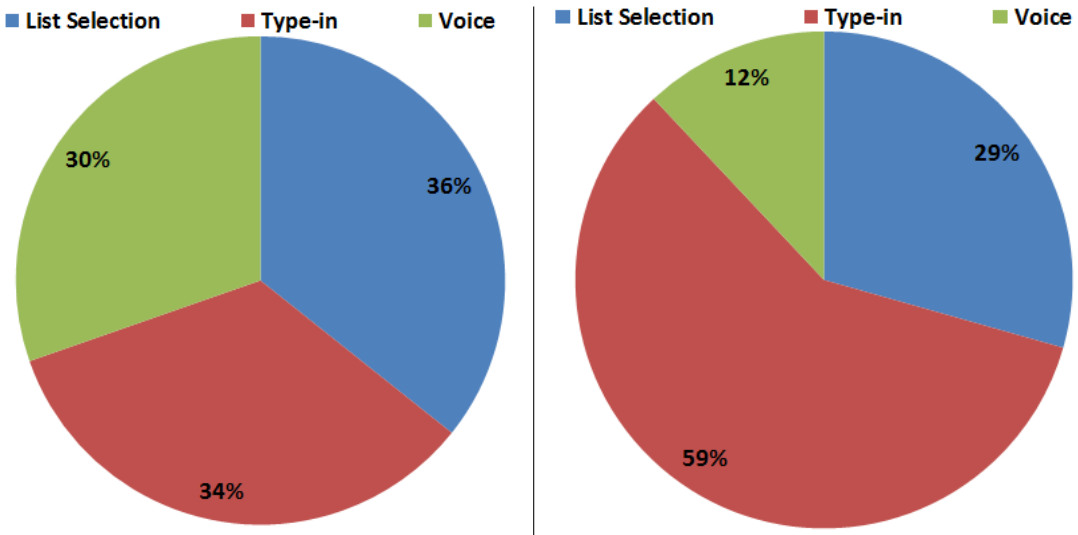
All the secondary caregivers preferred the gaming interface. They thought that while the gaming interface was "fun" and "cool", the non-gaming interface was "dull" and "boring". When I asked SC4 if she used the non-gaming interface, she said, *"The non-gaming ... I went to it like once, I thought it was kind of like different. I thought it was like blank, it was like black, it wasn't really as cool, and you just put in snacks or whatever and it shows you and stuff. I don't know, I thought the game one was more fun."*(M4). Similarly, SC1 said, *"It is a little bit boring, its basic and good for the parents."*(M3).

One secondary caregiver mentioned that the gaming interface was fun because of graphics, SC5 said, *"It [gaming interface] was more fun, more graphics I guess."*(M4). The secondary caregivers also said that the gaming interface was more motivating to eat healthy: *"I'm using the non-game one right now, but the game one it was nice, it kept you motivated to eat good."*(M4). Another secondary caregiver, SC2 found the non-gaming interface complicated, she said, *"It [non-gaming interface] was kind of weird because the stars would change through what day you were eating. And I was like: 'well that's complicated' and so I just went to the game."*(M4).

7.5.9 Multiple Input Mechanisms

As described earlier, Snack Buddy provided users with three different ways of entering a snack: (1) voice input by speaking the snack name, (2) typing-in the snack name, and (3) selecting the snack name from a pre-defined list. Since typing-in and list-selection are standard input mechanisms for various applications, I explored in detail what the target population thought about voice input since it is still not a common way of interaction for most users in diet management applications. I found two primary caregivers and one secondary caregiver who preferred voice input because it was a convenient and a faster way of interaction.

As shown in Figure 7.11a, overall, the primary caregivers used all the three input mechanisms fairly equally. I found that some primary caregivers preferred voice input because it was perceived as being quicker than other input mechanisms; PC3 elaborated on this: *"I usually do the voice,*



(a) Primary caregivers

(b) Secondary caregivers

Figure 7.11: Snack input mechanisms usage breakup; primary caregivers used all three mechanisms fairly equally; secondary caregivers preferred typing-in the snack names

it's just quicker to do the voice recognition."(M3). However, PC3 also observed that with the background noise, sometimes the voice recognition does not work properly: *"Sometimes it's hard, well I know with umm, sometimes it's hard to get it to understand you. She [SC3] was trying to put something in and I guess, sometimes it depends on the background noise for the voice recognition, that's usually how we do the snacks. And, she [SC3] was trying to do it outside tonight, but we were near a bunch of traffic so I knew that it wasn't registering. And I know last night and also tonight, one snack I had to try like 3 attempts to get it to actually understand what I was saying. It would like stop with the voice recognition and it would just sit there and have the little thinking mode."*(M3).

I found similar usage trends across multiple participants where they initially tried different input mechanisms, but later on in the study heavily adopted one mechanism. For example, as shown in Figure 7.12, PC4 preferred voice input towards the end of the study: *"I love where you can speak and say what you are eating, and then it will, you know, tell you: give you a picture if needed."*(M4). She also mentioned that it was convenient for her to speak, especially when she was behind the wheel: *"the speaking, cus it's easier to just say it real quick you know, while you're driving you speak it real quick. You know, 'let me enter this real quick' and then boom, there you go."*(M3).

Some primary caregivers preferred typing the snack name because they were used to it. When I asked PC2 what she thought about voice input, she said, *"It is a good feature but I'm just used to typing stuff."*(M4). Another primary caregiver, PC5 did not use voice input because she did not know about it. Even when I informed her about the feature in the mid-intervention meeting (M3), she said that it was too complicated and she would resort to either typing-in or selecting from the snack list. PC1 also either typed-in the snack name, or selected the snack from the list. She said that she preferred the list selection because going through different snacks in the pre-defined list provided her information about the healthiness of different snacks. PC1 further mentioned that she tried using the voice in the beginning, but it did not work, so she never considered using it afterwards.

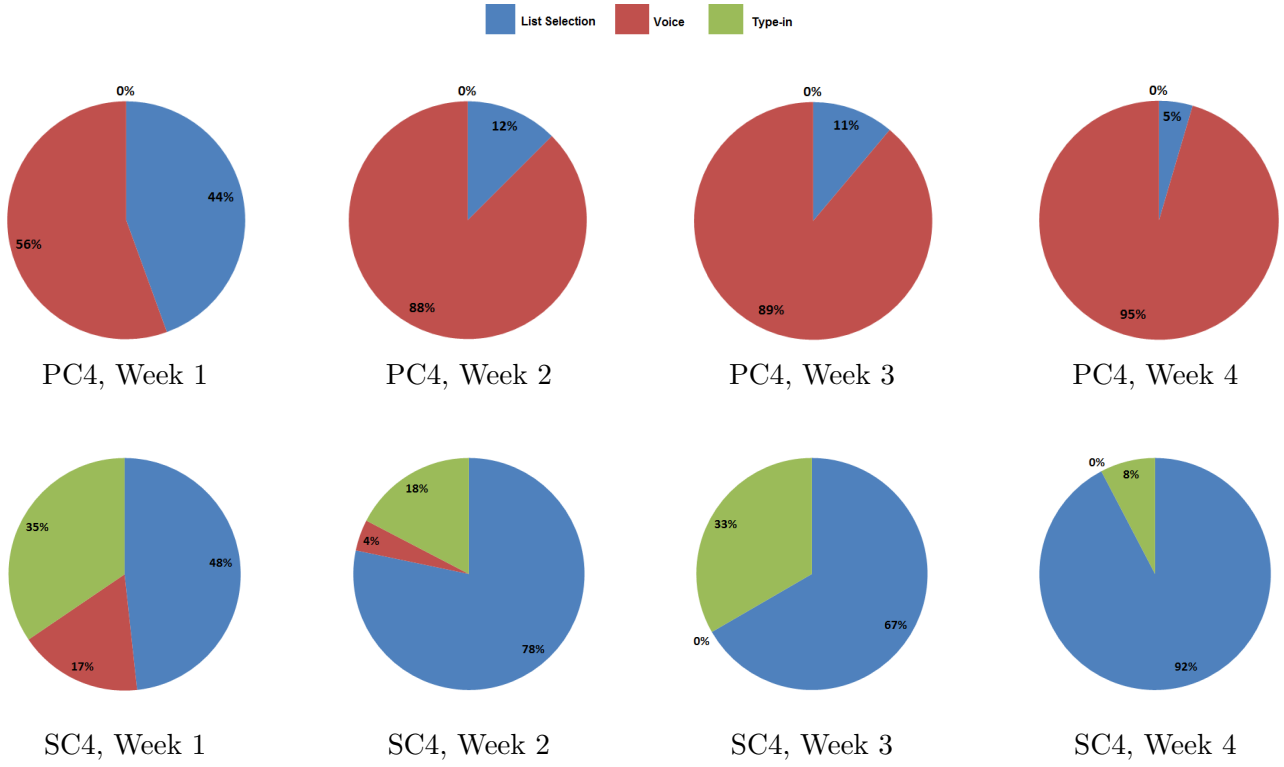


Figure 7.12: PC4's and SC4's snack input mechanism patterns were typical examples of how the users shifted from using multiple snack input mechanisms in the beginning to heavily adopting a single input mechanism towards the end of the study

As shown in Figure 7.11b, the secondary caregivers preferred typing-in the snack names because of their text-messaging habits, or the school environment where they were not allowed to use phones. SC2 mentioned how her environment affected which input mechanism she used, *"I think that both [voice and typing] are useful, because at school we are not allowed to use our phones, so like I would type it in, and then at home I would use voice."*(M4).

Only one secondary caregiver, SC3 preferred voice input, but if it did not work, then she would resort to typing-in the snack name: *"Usually I speak them, but if it doesn't pick up my voice like mom said today, when there's a lot of traffic noise, I like type it in as we're walking."*(M3).

Similar to primary caregivers, the secondary caregivers also showed a trend where they tried using multiple input mechanisms in the beginning, but settled on their preferred input mechanism towards the end of the study. As shown in Figure 7.12, SC4 initially tried all the three input mechanisms, but used list-selection heavily towards the end of the study.

I also found cases where secondary caregivers used list-selection initially because of the snack pictures but after that initial excitement, started typing-in the snack names. For example, SC5, who mostly typed-in the snack names said, *"The first few days I got it [Snack Buddy] I liked looking at the list to see what you guys already have. I liked doing that more, it is interesting to see all the little pictures."*(M3).

7.5.10 Using Snack Buddy in Everyday Life

For any intervention to be successful, it is important that it integrates well with the users' everyday routines. Therefore, during the interviews, I discussed with the participants about how they used Snack Buddy in their daily lives. Different participants had developed different habits of using Snack Buddy. Some participants preferred using it either before or immediately after eating the snack as mentioned by PC3: *"Sometimes there are a few I haven't entered because I had forgotten because it just put the time that you're recording it in there and if you've had earlier in the day then it doesn't really help, umm ... so there are times that I don't do it, but I'll either do it right before I'm going to have that or after I've had it. Pretty close to after I've had eaten it*

if I remember. Cus there's some that I know I'm going to have a handful of almonds so I'll put that in right before I have the almonds. And there are times that I'll have a few little snacks, a few different things and so I'll put them in after I've eaten so ..."(M3).

Another primary caregiver mentioned that they used Snack Buddy according to their convenience, PC4 said, *"I try to grab my phone while I'm at work, but sometimes, you know, they get real ... about that. I try not to pull it out, but as I remember I try to put it in. I think there was a few times that I entered it like really late and stuff."*(M3). PC1 mentioned that although she sometimes entered the snacks at the end of the day, but thought that it was of limited use because the user could not act upon the suggestions: *"I tried to remember it as well while I was eating but a lot of times I did find myself at the end of the day going in and putting everything in there. And then I felt that kind of defeats the purpose of the app if it gives suggestions of what you could eat at that time."*(PC1, M4).

The secondary caregivers everyday routines were different than the primary caregivers because they went to school. So when I discussed their usage of Snack Buddy in their everyday life, most of them mentioned how school affected their usage of Snack Buddy. For example, SC2 said, *"Only at school, at school I don't enter them because we're not allowed to have our phones at lunch otherwise we'll get it taken away. So when I get home I enter my snacks."*(M3).

Most secondary caregivers preferred entering the snacks before they ate it as highlighted by SC3, *"Well I like, it will depend on like before eating them and while eating them, cus sometimes if I forgot before I started eating I'll be like 'shoot! I didn't enter my snack in', so I'll do it afterwards."*(M3). One secondary caregiver, in particular thought that entering snacks after eating them defeated the purpose of using the application because the user could not act on the healthier snack suggestions: *"If we do it that way [enter snacks after eating them], it's a slower process to be healthier, because we put it in after we eat it and then later on we check and we are like: 'oh we are not eating healthy' and then we fix it. But if we do the before thing then it's like: 'oh, we need to fix it now'."*(M4).

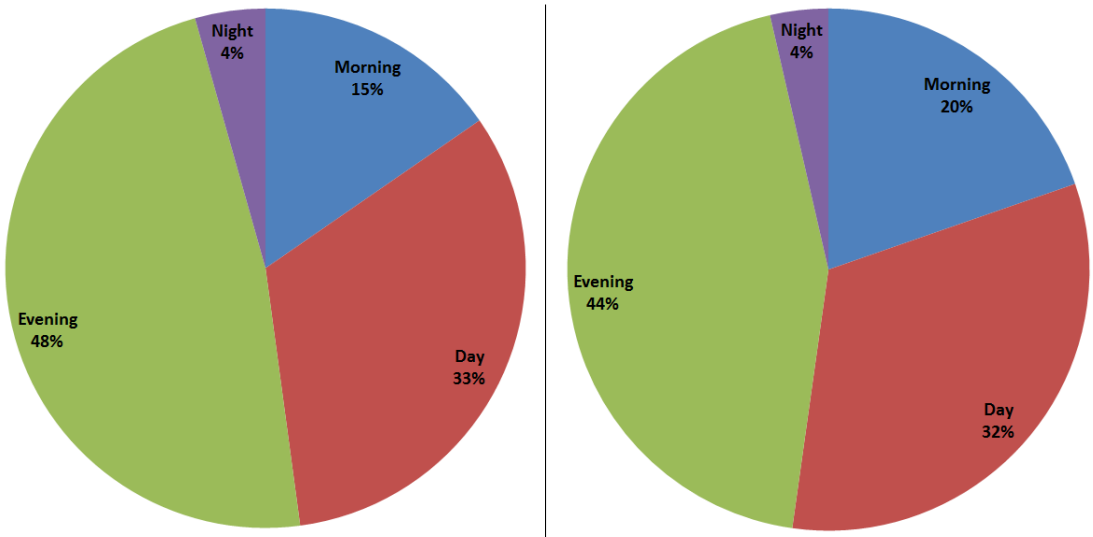
Towards the end of the study, I also asked the participants if they had an option to get

Snack Buddy on their mobile phones, would they use it continuously. All participants mentioned that they would use it in their everyday life. PC4 asked me if she could have the application on her phone, she further said, *"I would use it if I was able to have it on my phone I would use the application"*(M4). PC2 and PC5 explicitly asked me if they could have the application on their phones. Similarly, the secondary caregivers inquired if the application would be available on Google Play. SC1 was very keen on using it: *"I would like to see this application out on mobile phones. This application was good to me ... I tried some other apps on Google Play, but they weren't as good as this one ..."*(M4). SC3 specifically mentioned that she would want to continue using the application because it provided her information about which snacks were healthy. Other secondary caregivers also told me that the application helped them in improving their eating habits, and that they would want to use it continuously.

As shown in Figure 7.13, both primary and secondary caregivers used Snack Buddy mostly during the day and evening. The secondary caregivers used Snack Buddy slightly more than the primary caregivers in the morning slot which ranged from 12AM to 10:59AM. However, most of their usage was between 6AM and 8AM when they ate something in the morning before heading out to school, and 9AM and 10AM, when they typically ate something at school. Evening usage for both primary and secondary caregivers was highest within their respective usage times, because sometimes they could not enter their snacks during the day, so they would enter the snacks in the evening.

7.5.11 Messaging

Snack Buddy provided users with the ability to send messages to their family members who were using the application. While the participants tried the messaging feature just to explore it, they did not extensively use it because they regularly saw each other and preferred talking face-to-face. In total, forty-one messages were sent by the caregivers during the four-week intervention phase; these messages generally revolved around participants' everyday schedules. For example, PC2 sent following message to SC2: *" hi did u do good at school today"*, and *"hey can u plz finish*



(a) Primary caregivers (b) Secondary caregivers

Figure 7.13: Snack Buddy usage times by caregiver type; Morning: 12AM - 10:59AM; Day: 11AM - 4:59PM; Evening: 5PM - 9:59PM; Night: 10PM - 11:59PM

the house." Some conversations revolved around healthy eating, PC5 asked SC5: *"hello. ..r u eating healthy"* on which SC5 replied, *"yes!"* I also saw instances where the primary caregivers reminded the secondary caregivers about entering their snacks in the application, for example, PC4 said to SC4, *"your dad text me and will be there for the kids. have a good day. Enter your snacks today."* Only one participant, PC3 did not send a single message to SC3 even though SC3 sent PC3 two messages. When I explored the reason in the semi-structured interview, PC3 mentioned that she did not notice SC3's messages - she expected that the application would notify her about the new messages as an SMS. However the application only provided an *in-app* update on the home screen where it highlighted the new messages received on the "Messages" button. It also did not play any sound on receiving new messages. Moreover, I also found out that while PC3 was at work, SC3 would frequently call her to discuss her day, which may have contributed to PC3 not sending a message using the application.

7.5.12 Participant-Researcher Communication

One of the features of Snack Buddy was the "Message Danish" button where users could send me a message for any reason. Only two users, PC5 and SC3 used this feature, and although my primary motivation to design it was so that users would use it whenever they had any question about the application, they used it quite differently. PC5 used it to setup our meeting times for interviews, an example of her message is: *"Can u guys come around 7pm this Sat? My kids have karate from 3 to 6 pm."* On the contrary, SC3 used it to inform me about her game progress where she sent me messages such as, *"SECOND GOAL ACHIEVED!!!!!"* and *"I'm ahead of my mom."* Although not extensively used, this type of feature could have the potential to facilitate the communication between researchers and participants during a study.

7.5.13 Areas of Improvement

During the interviews, I discussed areas of improve in the application. The majority of participants suggested that the application should have more snacks and foods in its database. The

primary caregivers mentioned that a lot of their food was different than what the application had, and not being able to immediately find its health value was a major limitation. For example, PC2, who most consistently used the application throughout the study, mentioned this shortcoming: *"... like the snacks and candies and stuff that we eat that are different. And there is no [healthiness] value for them. And so that was kind of hard"*(M4). Similarly, PC4 also complained that the application had limited snack choices, when I asked what would she change in Snack Buddy, she replied, *"having more [snacks] because you have your set of snacks but then I was eating stuff that wasn't on there so it was entered as a new snack. And I really never knew if it was good or bad"*(M4). Here PC4 mentioned that she never knew if the new snack was good or bad despite the application updating the healthiness of new snacks within one to two days. However, since the participants were not explicitly informed about an updated snack rating, it is possible that they did not immediately see the updated snack healthiness. PC5 mentioned similar concerns with the application, *"sometimes I eat something but it's not on the list and then I have to write it out. But then I don't get any results [healthiness value]"*(M4).

An interesting suggestion made by PC5 was to record the location information in the application displaying if the food was eaten at home, restaurant, or at school. She said that her colleague recently told her that while viewing her bank statement, she realized she was spending too much on eating out. This triggered PC5 to think about how much her family ate at the restaurant because it was expensive and unhealthy. She said it would be a useful feature if the application provided the ability to track eating location: *"... a category where you would ask: 'did you eat this food at home? restaurant? or school?' because then the person realizes: 'oh my god how many times I have been eating out?' "*(M4).

Although I told the participants to use Snack Buddy to track their snacks, one primary caregiver, PC1 tracked her meals in addition to her snacks. She naturally found it difficult to manage meals on Snack Buddy since it was not designed for that purpose. PC1 however suggested that we should include meals in Snack Buddy: *"I think it could expand into the meals because I was recording meals and snacks on the application."*(M4). PC4 and PC5 agreed that tracking meals on

Snack Buddy would be beneficial.

The secondary caregivers, similar to primary caregivers, mentioned that the application did not have all the foods that they ate. They pointed out that the application lacked their cultural foods, for example, SC2 said, *"We eat mexican food a lot and they didn't have them in there. So I created a new snack."*(M4). Similarly, SC1 suggested that the application should have more *"products"* on it.

Some secondary caregivers pointed out that the application did not have portion sizes, which would have been a very useful feature. SC4 cited this concern in addition to lack of foods: *"... it didn't have a lot of foods in there, and so I would be like: 'oh I don't have it' so I wouldn't put it in or I would try to size it down or narrow it down to one thing. Like something smaller than I was actually eating, or I just wouldn't put it in at all because it didn't have it."*(M4).

Most of the other feedback from secondary caregivers revolved around how to make game more engaging. They wanted the game to be closer to the natural world and more relatable by providing them with multiple options at each decision point. For example, one of the goals provided by the game was to get a job for the game character. SC3 played cello in her spare time and suggested that the game should provide the ability to select the game character's career field as she wanted the character to become a music teacher. Similarly, another goal provided by the game was to buy a couch to furnish the game character's house. SC5 suggested that it would be "more fun" if the game provided the option to select from different couches.

Apart from an increased relatability, the secondary caregivers asked for more personalization. When I asked SC2 what would she change in the game, she said, *"... like you can them make their own avatar but that is pretty much it. It was a really cool app."*(M4). SC2 added that the game could be more engaging if it provided the ability to keep a virtual pet: *"... if we had to get pets and stuff, that would be cool because then you would want to make sure that is fed well and she's doing good and yeah... that would be cool"*(M4).

7.6 Discussion

The field trial results showed that Snack Buddy was used both by primary and secondary caregivers, and that it improved their awareness about healthy eating and induced short-term healthy eating behaviors. Since there were a variety of factors involved in the design of Snack Buddy, it is important to discuss these different facets and their effects on the target population. I first discuss how designing Snack Buddy based on SCT facilitated short-term behavior change in the target population. I then highlight the importance of interfaces that employ demographic-specific engagement strategies to engage users from different demographics to a single application having common health objectives. Here, I also discuss in detail how to effectively design gaming mechanisms in a sociotechnical intervention to improve health behavior in the target population. I further discuss design implications noting the importance of community-based interventions in a multicultural environment to facilitate participant sharing. Finally, I discuss the value of having just-in-time feedback in a sociotechnical dietary intervention, and how real-time dietary information acquisition systems could further enhance the adoption of these interventions.

7.6.1 Sociotechnical Intervention Design for Health Behavior Change

I found that field trial participants had short-term eating behavior improvements - both immediately following the application use period and during the six-week follow-up. I found a significant improvement in the overall healthiness of the foods reported by the participants during the post-intervention PEI as well as an increase in the relative proportion of their diet that is made-up of fruit. I also found a positive change in the overall healthiness of foods reported by participants over the eight different 24-hour food recalls across the entire twelve-week study. This suggests that mobile application-based interventions informed by a comprehensive needs assessment and a rigorous user-centered design process, have the potential to actually affect behavior change, both in the short-term and potentially in the longer term.

7.6.1.1 Increasing Awareness about Personal and Family Snacking Behaviors

My qualitative data suggests several potential mechanisms that may have led to the change in eating behaviors that I found - personal awareness and intentions, family awareness and social norms, and self-efficacy. The first is an increased awareness of personal snacking behaviors that then empowered participants to make different decisions about the snacks and food they ate. SC4 summarized this change in awareness when she said, *"I was always like, I don't eat a lot, but I do. I actually do eat a lot, and I do eat unhealthy. And so it made me realize I need to start eating better for myself."* Many participants identified this change and then associated it, as did SC4, with increased intentions to eat healthier, which may be one of the key mechanisms by which they actually enacted behavior change. Behavior change theories suggest that, although intentions do not guarantee behavior change, they are one of the strongest predictors of change [54].

Participants also identified ways that the application increased their awareness of their families' snacking and eating habits. The primary and secondary caregivers that used the application reported that seeing their families' snack information helped them improve their behaviors. All of the primary caregivers would look at their children's snacks in the application and identify snacks that they could have eaten instead that would have been healthier. This motivated them to change what they were serving their child or what was available in the house. SCT posits that the social context and environment in which a person operates are major factors in determining their behaviors. My application may have caused primary caregivers to engage in conversations with their children about healthier food or driven them to change the environment for their children. Parents are a major social force in the lives of children and can shift their children's behaviors.

7.6.1.2 Establishing healthy norms by social influence

Secondary caregivers were able to see the average healthiness of the snacks that their parents ate, which may have influenced them in two ways - creating a competitive environment and establishing healthy norms. Secondary caregivers highlighted their joy of *"battling"* and competing with

their parents, which they reported would *"motivate [them] to have more healthier snacks"*(SC3). Although some primary caregivers enjoyed this *"friendly competition"*(PC1) as well, it was primarily the secondary caregivers that enjoyed the competition and cited it as a reason for changing their eating behaviors. This finding is consistent with work by Maitland and Sherwood [134] in the related domain of physical activity, which found competition as an effective social strategy for initiating behavior change. However, my research differs from other competition-based interventions [55, 131] because the competition was between parents and children as opposed to competition between individuals that consider themselves peers. This suggests that competition is an effective design strategy for behavior change, not only for people that consider each other peers, but also within families and between individuals of different ages and with different roles in their settings.

In addition, parents could establish healthy norms for their children within the application by eating healthy and maintaining a high average snack healthiness. SCT, and other behavior theories, suggest that norms can effectively influence an individual's behaviors and that those people that are closest, such as parents, have the greatest effect. My results are consistent with these theories both in my qualitative data and my quantitative data, in which I found a difference in family snacking awareness from pre to post-intervention that approached significance, even with a small sample size. The idea of social norms in SCT provides one possible explanation of how an increase in family snacking awareness would lead to behavior change [14]. This influence could also work in the other direction where the children might influence their parents. Simply knowing that their children could see the healthiness of their snacks may have driven parents to eat healthier to model better dietary behaviors for their children or to avoid criticism from their children.

7.6.1.3 Concrete, Actionable Recommendations

Both primary and secondary caregivers reported acting on the recommendations provided by the application. For example, PC2 decided to eat almonds or bananas instead of chips because of the suggestions she saw from the application. SC2 took the advice of the application and ate a chicken burger instead of a ground beef hamburger after receiving the snack suggestion. These are

just two of many examples provided by the participants that suggest an increase in their self-efficacy based on making small changes in their diet. After adopting the suggestion to eat a chicken burger, SC2 then looked at the next set of suggestions that would be healthier than a chicken burger and felt confident that she could act on that information. SC3 demonstrated leveraging her personal experiences when she looked back at her snacking history and identified specific unhealthy snacks, that she could have replaced with healthier ones. The snack history was a useful mechanism by which participants could reflect on their personal experiences, which SCT posits, would lead to increased self-efficacy, possibly accounting for the observed change in behavior I found. Although I did not explicitly measure the effect of the application on self-efficacy, the qualitative data strongly suggests that participants increased their self-efficacy around eating healthier foods.

My data suggests one last mechanism that may have accounted for the observed behavior change, a change in the availability of foods. I found a significant increase in the amounts of fruits participants in the intervention group ate in their diet. In addition, I found an increase in the availability of fruits that approached significance for the intervention participants. Participants may have purchased more fruit based on feedback from the application, which would change their environment and lead to behavior change. Participants may also have simply become more aware of the fruit that was in their home already, leading them to eat more of that. I do not have clear data that supports either hypothesis, but both hypotheses would support the idea that the application was able to affect the environment or the participants' perception of the environment, which would in turn lead to behavior change. This interpretation is consistent with SCT, where changes in the social context and environment are strong predictors of behavior [14]. This idea is also consistent with previous research that suggests an increase in availability of healthy foods leads to increased consumption of fruits, vegetables, and other healthy foods [15, 98, 162, 194]. Here, I would also point out that many previous studies [110, 135] with low SES populations have acknowledged that there are intractable variables, such as income, environment, and lack of transportation, that are major barriers to healthy eating. But the field trial data shows that the target low SES population found a way to bring more fruits in their lives, and adopt healthy everyday dietary behaviors.

7.6.2 Demographic-Specific Interfaces

The field trial results showed that, although the participants had a choice to select the gaming or non-gaming interface, they stuck with the interface that was specifically designed for them. This highlights the importance of understanding user's demographic-specific needs and then translating them into appropriate interface designs that engage them in achieving a well-established health goal. My needs assessments showed that primary caregivers wanted to manage their family health and the non-gaming interface design captured this essence by visualizing the average healthiness of different family members and providing the primary caregivers the ability to view detailed snacking habits of their loved ones. The building blocks for the non-gaming interface visualizations were star representations of snack healthiness. To highlight why I used them, I will quote a primary caregiver from the prototype evaluation study: *"Maybe it's the childhood thing. We always got stars for doing well. And so ... As a token of appreciation and as a token to continue to do better ... it's like a psychological imprint that's been put into our heads since I was little kid."* I leveraged this psychological imprint and developed interfaces with which the primary caregivers could easily relate. Indeed, the primary caregivers mentioned how much they preferred the star representations during the field trial. PC4 said, *"I loved the star rating. I was always trying to, I wanted to get to the max and it never got that high. But talking last time you said: 'you know I was still doing good.' So I was happy. I am you know, eating healthier."*

The secondary caregivers, on the other hand, found star representations boring, dry and dull. They preferred gaming mechanisms with rich graphical visualizations that motivated them to compete against other family members. I developed the gaming prototype based on these design considerations, and sure enough, all secondary caregivers enjoyed playing the game while at the same time reporting improved snacking habits. Researchers in the HCI-field have developed dietary interventions targeted towards adolescents [35, 167], and adults [84, 90], however they do not provide mechanisms to facilitate a family-wide initiative to improve diet. This is where I believe the demographic-specific interfaces can fill the gap by engaging the entire family towards healthy

habits. In fact, Snack Buddy provides a concrete example of how an application can use a single underlying framework, but display data in different, demographic-specific interfaces.

I believe that the demographic-specific interfaces were one of the key features that led to the behavior change I found in the field trial data. This point would be consistent with previous research that demonstrated that tailored interventions promoted short-term health behavior change [151, 152]. While I successfully used demographic-specific interfaces to induce healthy eating behaviors in the target population, for researchers and designers, there is a cost associated with creating these interfaces - time. Developing an application with demographic-specific interfaces requires significantly more time than an application with a single interface. The resource demands also depends on the complexity of the interfaces. Ultimately, there is a trade-off between developing demographic-specific interfaces that require more time versus developing a single interface that designers modify in multiple design/development iterations to satisfy the needs of different types of users. Further research is required to evaluate how a single interface that employs some elements of gaming mechanisms and some elements of management-style visualizations, would be received by families as a sociotechnical intervention to improve their health behaviors.

7.6.3 Multiple Input Mechanisms

Snack Buddy provided users with the ability to enter snacks in three different mechanisms: (1) typing-in the snack name, (2) speaking the snack name, and (3) selecting the snack from a predefined list. As shown in the findings, different participants found value in different mechanisms. Users who preferred voice input found it faster than the other two mechanisms. Users who preferred to search from the snack list mentioned it was fun going through all the snack pictures and also educative since it provided healthiness rating of different snacks. Finally, users who preferred typing-in snack name did it because they were used to typing-in and found voice input complicated and selecting a snack from the list too slow. I also showed how users tried different snack input mechanisms in the beginning but then settled down with their preferred mechanism towards the end of the study. This highlights the importance of providing flexibility to users in terms of multiple input

mechanisms - HCI designers should not force their preconceived ideas about how users might prefer input mechanisms, rather provide a choice to the users where they figure out themselves what best works for them. Their choice can vary based on a variety of factors including technology-literacy, past experience and interaction habits, location of usage, and personal preference. Providing users a variety of options actually makes an application more usable in different circumstances. For example, I found that while driving, the participants preferred voice input, however when at school, they preferred entering by list selection or by typing-in. Multiple input mechanisms can significantly contribute to the pervasive nature of an application, making it usable by a variety of users in different contexts and surrounding environments.

7.6.4 Designing for Community

The findings revealed that the participants discussed the application with their friends and family, who showed a keen interest in the application and also inquired if it was available to general public. This suggests that if the application was freely available online, it could have spread virally by the means of friends and family networks. There is a lot of potential for this as a community-level intervention where friends and family members can easily share and track their dietary habits. In the findings, I showed examples where friends, colleagues, and family members who were not using the application changed some of their eating habits because of the influence of individuals using the application. We can leverage on and broaden these vicarious experiences whereby many individuals can exponentially affect and improve the eating behaviors of those whom they frequently interact with. Therefore, as HCI designers and researchers, in addition to focusing on individuals, we should keep a broader vision of designing for the community, potentially allowing the application to seamlessly synchronize with friends and family.

While there is a lot of potential for designing mobile dietary applications for community, it also raises serious questions about design implications for an application that can be used to track and share dietary information. Imagine a scenario where a teenager's friends want to share their eating habits on the application but the teenager's mom knows that those friends have unhealthy

eating habits; would she be concerned that her child might adopt unhealthy eating behaviors from his/her friends? Consider another scenario where a colleague who frequently snacks on fast food shares her eating habits with mom, would this mom somehow want to hide her colleague's eating habits from her children since we often saw secondary caregivers using their parents' phones. It means that rather than open sharing, the sociotechnical intervention should have mechanisms for "moderated sharing" where family decision makers can manage the sharing and privacy of their family's dietary information. Another suggestion to mitigate this problem is to have built-in mechanisms in the application that make sure it is not perpetuating unhealthy social norms around eating behaviors. For example, the family decision maker can have an option to set a threshold value of food healthiness below which, the unhealthy foods are not broadcasted and shared across their children's friends. This would only propagate the positive dietary behaviors while at the same time making the primary caregiver feel comfortable knowing that their child are not being exposed to negative dietary norms.

The final implication while designing for community is the inter-cultural dietary interaction. In the field trial, all the dietary sharing was done within a family, who were from same culture. However, as I mentioned earlier, the Bridge Project consists of ethnically diverse population, and secondary caregivers in particular have friends from other ethnicities and culture. In this scenario, there is a potential where a Hispanic child shares her eating habits with an African American friend. Although we know that the application works well for individuals from different cultures, including Hispanics, African Americans, Asians, and Caucasians, we need to investigate how we can support cross cultural sharing and interactions through sociotechnical interventions. In fact, different researchers have designed culturally-focused health interventions. For example, Karanja et al. [106] designed a weight loss intervention specifically for African American women. Other interventions [73, 118] have adopted a faith-based approach where researchers have utilized churches and spiritual places to promote health-related activities. Moreover, Grimes et al. found that users preferred sharing their health information that was culturally and locally focused [84]. In a comprehensive dissertation on the relationship of health technologies and culture [163], Andrea

Parker emphasizes that *"HCI designers should closely examine the interplay of culture and health and how technology might disrupt, resonate with, reflect or reject this interplay."* Indeed, research has shown that considering cultural sensitivities can increase retention by up to forty percent in family-based intervetions [122].

While most of the HCI literature highlights the importance of the technology-culture relationship, the field trial raised questions about technology-cross cultural relationship. For example, during the field trial, there were different cultural foods that I did not understand; the sociotechnical intervention should have mechanisms to translate these foods so they are understandable by people from foreign cultures. A simple solution is to have a small popup that displays a brief description about the food and can identify an example of a similar food from that person's culture. Another example also comes from the field trial where PC1 told me that she had decided to stop eating McDonald's during Lent, a Catholic holiday in which families give up certain types of luxuries for around six weeks. Imagine if PC1's friends from other cultures eat lots of McDonald's fast food that frequently shows up on the sociotechnical intervention. To counter this situation, the application can have a filter that limits the incoming feed of specific food items for a specific duration of time. The sociotechnical dietary interventions therefore should have mechanisms that deal with the various problematic situations that could arise due to cross-cultural dietary sharing.

7.6.5 Game Design for Healthy Eating

The game-based interface was a major part of Snack Buddy that engaged the secondary caregivers, leading to increased, consistent application use and motivation to compete against their family members. While creating the low-fidelity gaming prototype was fairly straightforward, there were numerous design considerations involved when it came to translating a low-fidelity prototype to a functional gaming application. Here, I discuss the key challenges that I faced in developing the gaming interface and provide secondary caregiver's feedback that informs how future sociotechnical interventions could leverage different gaming mechanisms to be more effective and engaging.

7.6.5.1 Game Pace

For Snack Buddy, individuals progressed through the game based on the the number of points that they accumulated from eating healthy snacks. How quickly an individual progressed through the game, which is the game's pace, was dependent on the number of points required to achieve sub-goals and levels. If too few points were required, users would not feel challenged and could easily get bored. Moreover, the game could end too quickly if the stages did not have enough content or new, interesting stages to achieve within the game. It was therefore important to strike the right balance between being challenged by the game and the ability to beat different levels that provided users a sense of satisfaction. Indeed, four secondary caregivers thought the game pace was just right. When I asked SC2 about the game pace, she said, *"It was like in the middle ... because sometimes if I didn't eat right I wouldn't get anything and I had to like achieve points to get what I wanted. But sometimes I would get through stuff really quickly. But it was pretty much even most of the time."*(M4). SC4 also had similar thoughts about the game pace: *"it was just the right pace because every time I put in a certain snack it would give me points and I would be like oh I need this much more points to get a computer and it was just a fun thing to do"*(M4). Only one secondary caregiver earned everything possible, and thought the game was too easy.

Creating the amount of content necessary for continued, long-term engagement with the application can be resource intensive and potentially not scalable. We need to develop scalable solutions to expand the amount of content available to users if we are to realize the benefits of an engaging game. One potential solution, suggested by several secondary caregivers, would be to allow for user-generated content. Secondary caregivers in our study specifically suggested that they could create ways to customize their character like new clothes or a hat. They also suggested creating customizations for the items they acquired in the game such as drawing their own design on the couch they got for their in-game house. This concept of user-generated content could be expanded to allow users to create entirely new levels in the game or new items and goals to be achieved. This would allow users to extend the life of the game for themself, but also for others if

they are willing to share the new levels with other players. This may also serve as a mechanism to further engage people with the game, as there is research that suggests people are more invested in things that they create [153].

7.6.5.2 Relatability

Another important concept that I uncovered while designing the gaming interface was that the secondary caregivers wanted to be able to relate to the game character. The secondary caregivers wanted the flexibility of selecting the type of job that the game character got and the type of couch that the character bought for her house. In essence, they wanted to virtually live the life of the game character. To make Snack Buddy game more relatable, I used skin tones for the game character that matched most of the target population. Moreover, since there were Somali Muslim families in the target population, I even added a game character with a hijab. By increasing this sense of relatedness, HCI researchers can effectively utilize the transportation theory elements that suggest that individuals' behaviors can be affected by transporting them into immersive narrations. My findings suggest that the immersiveness of these narrations is strongly tied with the amount of relatability in the interface design.

7.6.5.3 Cheating

All the dietary interventions rely on self-reporting where the participants in different forms report what they ate. With this self-reporting, there is always a possibility of incorrect reporting, whether deliberate or unintentional. The deliberate incorrect dietary self-reporting translates to cheating while playing a sociotechnical dietary gaming application. What happens if a person does not eat something, yet she enters it in the system to collect points? While developing the application, I brainstormed several ideas to minimize cheating. For example, the game could have a limit of the maximum number of snacks entered in a day. The game could count multiple close healthy entries as one entry, for example, if the user enters broccoli five times in two minutes, the game could record it as one input. However, rather than enforcing these rules, I collected different

types of their eating data that enabled me to triangulate any suspicious input activity. Additionally, I thought that even if users entered healthy snacks that they did not eat, they would still be learning passively about healthy eating and might incorporate these practices in the future. Since it was an important topic, I asked the secondary caregivers what they thought about cheating, and most of them thought that cheating in a health game would be equivalent to deceiving oneself. For example, SC5 said, *"Well they are only cheating themselves, so if they if they are eating donuts and they put in that they are eating apples they are just going to get fatter, it's really their problem. Like if somebody is determined to become healthier then I think they would use it right."*(M4). During the field trial, I found one such instance where a secondary caregiver, SC3, recorded thirty-eight snacks in the first two days of using the application, however she deleted these snacks immediately afterwards. During the interviews, I found out that initially she thought that she had to enter all of her preferred snacks without necessarily eating them. But her mom told her to enter only those snacks that she ate. Based on my experience of developing the gaming application and then conducting the field trial, I would suggest that researchers not restrict the gaming experience to deter cheating, rather focus on developing study designs that benefit from gathering multifaceted dietary data that can be triangulated to detect suspicious behaviors which may be further investigated during the interviews.

7.6.5.4 Competition versus Cooperation

In Snack Buddy, the secondary caregivers were motivated to compete against the primary caregivers in eating healthier snacks. Although I found that competition worked successfully in Snack Buddy since all secondary caregivers mentioned they enjoyed competing against the primary caregivers, I still sought participants' feedback on cooperation. While most of the participants were not sure how that would work out, SC5 had serious reservations about it since she thought that would put unnecessary peer pressure on the players: *"I think that (cooperation) would cause a problem because we would be yelling at each other: 'eat this stuff, get more points.' "*(M4). I found that most of the secondary caregivers were competitive towards their siblings, and mentioned that they would enjoy competing against them. This was even cited by a primary caregiver when

I asked her if competing against siblings in the application would cause any family problems, she said, *"Are you kidding? It would be great, I don't know what it is with all my kids, but there is competition for everything all the time."*(PC2, M4). I followed up by asking wouldn't it get a little too intense? She replied, *"I don't think it would get too intense. But I think it would probably get a lot healthier."*(M4). Here, PC2 clearly identifies her children being more competitive in nature towards each other, this suggests that a dietary game based on competition is more likely to be successful than a cooperative game. Moreover, in a cooperative game, players would have to wait for others' turn to see progress, and if some players are not motivated to play the game, it might have negative impact on their fellow players, drawing them away from the application. However, more research is required to evaluate the positives and negatives of competition versus cooperation in a sociotechnical dietary intervention design.

Furthermore, our research suggests that interventions targeted at the family-level should provide users the flexibility to choose whether or not the game will be competitive or cooperative based on their family dynamics. If parents or children identify serious concerns with one of the gameplay formats, then they should be able to change it. However, the application should consider how those negotiations would occur between family members and that families may not all agree on the same gameplay format.

7.6.6 Just-in-Time Feedback and Dietary Information Retrieval Systems

Snack Buddy provided the users with the ability to view healthier snack suggestions when they entered a snack. Previous research, such as *EATWELL* [84] was designed to share nutrition experiences, but the users did not receive any feedback on those experiences. Pollak et al. [167] designed *Time to Eat*, where they added feedback into their application as a key feature, however the feedback was delayed because users would first send their food pictures to researchers, who would then manually provide feedback. Building on this prior work, Snack Buddy provided users with just-in-time feedback for all the snacks that were present in the database. Users overwhelmingly responded positively to this type of feedback, citing specific examples of recommended snacks that

they integrated into their diet. They also provided examples of situations when they decided to eat something healthier instead of what they were about to eat. This highlights the importance of just-in-time feedback and demonstrates how it can act as a mechanism to promote healthy behaviors.

What further underscores the importance of just-in-time feedback was participants' major concern about not receiving immediate feedback if the snack was not already in the database. I mitigated this problem by providing users with the ability to send the new snack, which would then be updated and broadcasted to all the clients. This meant that when the participants entered the same snack next time, they would receive the just-in-time feedback. A similar approach is used by Fooducate (fooducate.com), a famous mobile and web-based tool that provides users with the ability to lookup the healthiness of different food products by scanning their barcode or entering its name. Although Fooducate has over two hundred thousand unique food products in its commercial database, it still receives thousands of pictures from users each year about food items not available in the database [174]. While these are partial solutions, working on this problem opens up an avenue in automatic dietary healthiness research. One solution could be an information retrieval system that has online crawlers that perform natural language processing to gather and process snack healthiness information from different Internet resources. When a user enters a snack that is not present in the database, it could query a dietary information retrieval system which returns snack healthiness that could be presented to the user. In fact researchers have already conducted some research along these lines where they developed an Internet Information Retrieval system that ranked different webpages based on the quality of health-related food information that the page provided [175]. More research however is required to evaluate the feasibility and integration of these systems with sociotechnical dietary interventions that would in turn increase the overall user experience that may lead to a higher user adoption.

7.7 Conclusion

I developed a mobile application to help low SES families track, understand, and improve their snacking habits. The application allowed participants to enter the snacks that they ate throughout the day, receive healthier snack suggestions, review the snacks that they had eaten over time, and view the healthiness of snacks eaten by their family members. The application also had two interfaces - one designed for primary caregivers that focused on tracking family snack healthiness and one that engaged secondary caregivers with a motivational game. I deployed the application in a twelve-week field trial with one primary caregiver and one secondary caregiver from five low SES families, a total of ten participants. The field trial consisted of pre- and post-intervention PEIs, four weeks of application usage, and six week of follow-up. I also enrolled five low SES families into a control group that participated in similar study activities, however they did not use my application at all.

Overall, participants overwhelmingly preferred the application and wanted to keep using it, as well as share it with their friends and other members of their family. I found a short-term, post-study effect of my application on the overall healthiness of foods that participants ate and the amount of fruits in their diet. This change sustained across the six-week follow-up period, during which we found a significant improvement in the healthiness of foods eaten by the intervention group participants. Participants shared specific ways in which they had improved their snacking and eating behaviors because of the application. These ranged from replacing potato chips with almonds or fruit to eating fewer snacks.

My findings suggest that one reason for the intervention group participants' healthy diet change is an increase in snacking and diet awareness. Participants reported being more aware of their own snacking behaviors and those of their family members. Primary caregivers especially appreciated understanding the types of snacks eaten by their children throughout the day and identified ways that they could work with their children to improve their snacks. Another reason for the change in behavior may have been an increase in the healthy foods available for participants,

specifically fruit. Participants also suggested having more self-efficacy in eating healthy snacks and healthy foods after using the application. The idea that changes in their environment and self-efficacy would lead to behavior change is consistent with SCT and provides a positive outlook for theory-based sociotechnical interventions for health behavior change.

For the design of future sociotechnical interventions for health behavior change to be effective, it is essential to target specific theoretical constructs such as self-efficacy, social norms, and awareness. My findings suggest that it is possible to influence these constructs with a mobile phone application and in turn create behavior change towards healthier behaviors. I identified design strategies, such as actionable recommendations, social influence, and competition that were key in targeting these constructs. The demographic-specific interfaces in my study bolster a growing body of research that calls for more attention to individual needs in the design of interfaces. Providing primary and secondary caregivers different interfaces that met their unique needs was essential in achieving sustained use during the length of study. Furthermore, my research suggests a need to provide multiple input mechanisms within interfaces that allow users to explore what works best for them and adapt that strategy in their use.

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Appendix A

Prototype Evaluation Background Questionnaire Adults

The purpose of this questionnaire is to provide us with some background information about yourself, your family, and your experience with technology.

About You

Gender: Male / Female

Age: _____

Marital Status: Single / Married / Divorced / Living with Partner / Seeing someone

Ethnicity: Hispanic or Latino / Not Hispanic or Latino / Unknown

Race: American Indian or Alaska Native / Asian / Black or African American / White / More Than One Race / Unknown or Not Reported

Work Status: Not Working / Part-time / Full-time
If so what do you do? _____

Your Family

How many children do you have? _____

For each child that you have, please enter their age and gender in the box provided below:

Age	Boy/Girl

If anyone else helps you look after your children, please state their relationship to you (e.g. sister, friend) and what they do to help in the box below:

Relationship	What they do to help

Technology

1. Do you have a computer at home? Yes No
   If so, how often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

2. Do you have access to a computer somewhere other than your home?
   If so where? _____
   How often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

3. How much experience do you have using computers?

   a. Less than 1 year
   b. 1-2 years
   c. 2-3 years
   d. 3-4 years
   e. 4-5 years
   f. More than 5 years

One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the computer for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Email						
Shopping						
Internet (News, Browsing, etc.)						
Word Processing						
Instant Messaging						
Music						
Video (Youtube, etc.)						
Photos						

4. Have you ever made an online profile page that others can see, like on MySpace, Facebook or LinkedIn.com?

   a. Yes b. No c. Not sure

5. Do you own a mobile phone? Yes No
   If so, how often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

6. What type of mobile phone you have?

   a. Basic phone
   b. Touch screen phone
   c. Full keypad phone
   d. Smartphone

e. N/A

7. Do you have an Internet plan on your mobile phone?

   a. Yes b. No c. N/A

8. Have you ever used the Internet on your mobile phone?

   a. Yes b. No c. N/A

9. How much experience do you have using mobile phones?

   a. Less than 1 year
   b. 1-2 years
   c. 2-3 years
   d. 3-4 years
   e. 4-5 years
   f. More than 5 years

10. One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the mobile phone for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Make / Receive phone calls						
Send / Receive text messages						
Take photos						
Download applications (games, etc.)						

Health Insurance

11. Do you have health insurance right now?

    a. Yes b. No c. Not sure

12. IF YES TO QUESTION 12: Which of these is your main health insurance?

a. Medicare
b. Medicaid
c. I'm covered under my work insurance
d. I'm covered under my spouse's plan where they work
e. I buy my own insurance
f. Other:
g. I'm not sure

13. Write down all the snacks that you eat:

a. Chips _____
b. Cookies _____
c. Cheese _____
d. Candies _____
e. Crackers _____
f. Doughnuts _____
g. Chicken Burger _____
h. Orange _____
i. Ham Burger _____
j. Chicken Nuggets _____
k. Apple _____
l. Pastries _____
m. Strawberry _____
n. Chocolate _____
o. Banana _____
p. Milk _____
q. Cheese balls _____
r. Nachos _____
s. Soda _____
u. Broccoli _____
t. Carrots _____
v. Celery _____

Others:

_____

_____

_____

14. What are your top 5 favorite snacks?

1. _____
2. _____
3. _____
4. _____
5. _____

16. Where do you buy your groceries?

_____

Appendix B

Prototype Evaluation Background Questionnaire Teens

The purpose of this questionnaire is to provide us with some background information about yourself, your family, and your experience with technology.

About You

Gender: Male / Female

Age: _____

Marital Status: Single / Married / Divorced / Living with Partner / Seeing someone

Ethnicity: Hispanic or Latino / Not Hispanic or Latino / Unknown

Race: American Indian or Alaska Native / Asian / Black or African American / White / More Than One Race / Unknown or Not Reported

Work Status: Not Working / Part-time / Full-time
If so what do you do? _____

Your Family

How many siblings do you have? _____

For each sibling that you have, please enter their age and gender in the box provided below:

Age	Boy/Girl

What kind of errands you do for your family?

a. Cooking
b. Grocery shopping
c. Caring for siblings
d. Prepare snacks
e. Cleaning
f. Other: _____

If anyone else helps you look after your siblings, please state their relationship to you (e.g. sister, friend) and what they do to help in the box below:

Relationship	What they do to help

Technology

1. Do you have a computer at home? Yes No
   If so, how often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

2. Do you have access to a computer somewhere other than your home?
   If so where? _____
   How often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

3. How much experience do you have using computers?

a. Less than 1 year
b. 1-2 years
c. 2-3 years
d. 3-4 years
e. 4-5 years
f. More than 5 years
g.

One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the computer for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Email						
Shopping						
Internet (News, Browsing, etc.)						
Word Processing						
Instant Messaging						
Music						
Video (Youtube, etc.)						
Photos						

4. Have you ever made an online profile page that others can see, like on MySpace, Facebook or LinkedIn.com?

a. Yes
b. No
c. Not sure

5. Do you own a mobile phone? Yes No
If so, how often do you use it?

a. Everyday
b. A few times a week
c. A few times a month
d. A few times a year
e. Not at all

6. What type of mobile phone you have?

    a. Basic phone
    b. Touch screen phone
    c. Full keypad phone
    d. Smartphone
    e. N/A

7. Do you have an Internet plan on your mobile phone?

    a. Yes
    b. No
    c. N/A

8. Have you ever used the Internet on your mobile phone?

    a. Yes
    b. No
    c. N/A

9. How much experience do you have using mobile phones?

    a. Less than 1 year
    b. 1-2 years
    c. 2-3 years
    d. 3-4 years
    e. 4-5 years
    f. More than 5 years

10. One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the mobile phone for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Make / Receive phone calls						
Send / Receive text messages						
Take photos						
Download applications (games, etc.)						

Health Insurance

11. Do you have health insurance right now?

a. Yes b. No c. Not sure

12. IF YES TO QUESTION 12: Which of these is your main health insurance?

a. Medicare
b. Medicaid
c. I'm covered under my work insurance
d. I'm covered under my spouse's plan where they work
e. I buy my own insurance
f. Other:
g. I'm not sure

13. Write down all the snacks that you eat:

a. Chips _____
b. Cookies _____
c. Cheese _____
d. Candies _____
e. Crackers _____
f. Doughnuts _____
g. Chicken Burger _____
h. Orange _____
i. Ham Burger _____
j. Chicken Nuggets _____
k. Apple _____
l. Pastries _____
m. Strawberry _____
n. Chocolate _____
o. Banana _____
p. Milk _____
q. Cheese balls _____
r. Nachos _____
s. Soda _____
u. Broccoli _____
t. Carrots _____
v. Celery _____

Others:

_____

_____

14. What are your top 5 favorite snacks?

1. _____
2. _____
3. _____
4. _____
5. _____

16. Where do you buy your groceries?

_____

Appendix C

Prototype Evaluation Interview Guide

The purpose of this questionnaire is to provide us with some background information about yourself, your family, and your experience with technology.

About You

Gender: Male / Female

Age: _____

Marital Status: Single / Married / Divorced / Living with Partner / Seeing someone

Ethnicity: Hispanic or Latino / Not Hispanic or Latino / Unknown

Race: American Indian or Alaska Native / Asian / Black or African American / White / More Than One Race / Unknown or Not Reported

Work Status: Not Working / Part-time / Full-time
If so what do you do? _____

Your Family

How many children do you have? _____

For each child that you have, please enter their age and gender in the box provided below:

Age	Boy/Girl

If anyone else helps you look after your children, please state their relationship to you (e.g. sister, friend) and what they do to help in the box below:

Relationship	What they do to help

Technology

1. Do you have a computer at home? Yes No
   If so, how often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

2. Do you have access to a computer somewhere other than your home?
   If so where? _____
   How often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

3. How much experience do you have using computers?

   a. Less than 1 year
   b. 1-2 years
   c. 2-3 years
   d. 3-4 years
   e. 4-5 years
   f. More than 5 years

One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the computer for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Email						
Shopping						
Internet (News, Browsing, etc.)						
Word Processing						
Instant Messaging						
Music						
Video (Youtube, etc.)						
Photos						

4. Have you ever made an online profile page that others can see, like on MySpace, Facebook or LinkedIn.com?

   a. Yes b. No c. Not sure

5. Do you own a mobile phone? Yes No
   If so, how often do you use it?

   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

6. What type of mobile phone you have?

   a. Basic phone
   b. Touch screen phone
   c. Full keypad phone
   d. Smartphone

e. N/A

7. Do you have an Internet plan on your mobile phone?

   a. Yes b. No c. N/A

8. Have you ever used the Internet on your mobile phone?

   a. Yes b. No c. N/A

9. How much experience do you have using mobile phones?

   a. Less than 1 year
   b. 1-2 years
   c. 2-3 years
   d. 3-4 years
   e. 4-5 years
   f. More than 5 years

10. One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the mobile phone for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Make / Receive phone calls						
Send / Receive text messages						
Take photos						
Download applications (games, etc.)						

Health Insurance

11. Do you have health insurance right now?

    a. Yes b. No c. Not sure

12. IF YES TO QUESTION 12: Which of these is your main health insurance?

a. Medicare
b. Medicaid
c. I'm covered under my work insurance
d. I'm covered under my spouse's plan where they work
e. I buy my own insurance
f. Other:
g. I'm not sure

13. Write down all the snacks that you eat:

a. Chips _____
b. Cookies _____
c. Cheese _____
d. Candies _____
e. Crackers _____
f. Doughnuts _____
g. Chicken Burger _____
h. Orange _____
i. Ham Burger _____
j. Chicken Nuggets _____
k. Apple _____
l. Pastries _____
m. Strawberry _____
n. Chocolate _____
o. Banana _____
p. Milk _____
q. Cheese balls _____
r. Nachos _____
s. Soda _____
u. Broccoli _____
t. Carrots _____
v. Celery _____

Others:

_____

_____

_____

14. What are your top 5 favorite snacks?

1. _____
2. _____
3. _____
4. _____
5. _____

16. Where do you buy your groceries?

_____

Appendix D

Prototype Evaluation Task List

Task List for Mobile Phone Applications (Teenagers, Julia)

Julia is a 15-year-old girl who goes to school in the morning and helps her mom with house errands in the evening. Lately, Julia has been eating plenty of unhealthy snacks so she decides to do something about it.

Task 1: Julia has heard some good things about a mobile phone application that helps people in improving their snacking habits. She downloads the application and has to set it up. Julia also tells her family about this cool phone application.

Task 2: Coming back from school, Julia's friend offers her a candy cane, which she takes happily. In the evening Julia decides to use her new phone application to record her snack.

Task 3: The next day while watching TV in the evening, Julia grabs a bag of chips from her kitchen cabinet and remembers she should probably use the mobile phone application.

Task 4: While watching TV last night, Julia goes to bed late and in the morning, she is running late for her school. She quickly grabs a packet of pretzels and leaves for her school. Julia uses her phone application in the evening.

Task 5: While using the phone application, Julia wonders what snacks she had been eating over the last few days.

Task 6: As suggested by the application, Julia gets some apples from her grocery store and eats them. By now, Julia has developed a habit of using the phone application every evening.

Task 7: Julia tries to keep having healthy snacks and eats bananas the next day.

Task 8: Almost a week has gone by since Julia has been using the phone application. She decides to see what she has been eating so far.

Task 9: While using the phone application, she remembers that she told her family about the application, so she compares her own snacking with her mom Alice's snacking.

Task List for Mobile Phone Applications (Teenagers, Amna)

Amna is a 15-year-old girl who goes to school in the morning and helps her mom with house errands in the evening. Lately, Amna has been eating plenty of unhealthy snacks so she decides to do something about it.

Task 1: Amna has heard some good things about a mobile phone application that helps people in improving their snacking habits. She downloads the application and has to set it up. Amna also tells her family about this cool phone application.

Task 2: Coming back from school, Amna's friend offers her a candy cane, which she takes happily. In the evening Amna decides to use her new phone application to record her snack.

Task 3: The next day while watching TV in the evening, Amna grabs a bag of chips from her kitchen cabinet and remembers she should probably use the mobile phone application.

Task 4: While watching TV last night, Amna goes to bed late and in the morning, she is running late for her school. She quickly grabs a packet of pretzels and leaves for her school. Amna uses her phone application in the evening.

Task 5: While using the phone application, Amna wonders what snacks she had been eating over the last few days.

Task 6: As suggested by the application, Amna gets some apples from her grocery store and eats them. By now, Amna has developed a habit of using the phone application every evening.

Task 7: Amna tries to keep having healthy snacks and eats bananas the next day.

Task 8: Almost a week has gone by since Amna has been using the phone application. She decides to see what she has been eating so far.

Task 9: While using the phone application, she remembers that she told her family about the application, so she compares her own snacking with her father Ali's snacking.

Task List for Mobile Phone Applications (Teenagers, Ali)

Ali is a 15-year-old boy who goes to school in the morning and helps his mom with house errands in the evening. Lately, Ali has been eating plenty of unhealthy snacks so he decides to do something about it.

Task 1: Ali has heard some good things about a mobile phone application that helps people in improving their snacking habits. He downloads the application and has to set it up. Ali also tells his family about this cool phone application.

Task 2: Coming back from school, Ali's friend offers him a candy cane, which he takes happily. In the evening Ali decides to use his new phone application to record his snack.

Task 3: The next day while watching TV in the evening, Ali grabs a bag of chips from his kitchen cabinet and remembers he should probably use the mobile phone application.

Task 4: While watching TV last night, Ali goes to bed late and in the morning, he is running late for his school. He quickly grabs a packet of pretzels and leaves for his school. Ali uses his phone application in the evening.

Task 5: While using the phone application, Ali wonders what snacks he had been eating over the last few days.

Task 6: As suggested by the application, Ali gets some apples from his grocery store and eats them. By now, Ali has developed a habit of using the phone application every evening.

Task 7: Ali tries to keep having healthy snacks and eats bananas the next day.

Task 8: Almost a week has gone by since Ali has been using the phone application. He decides to see what he has been eating so far.

Task 9: While using the phone application, he remembers that he told his family about the application, so he compares his own snacking with his mom Amna's snacking.

Task List for Mobile Phone Applications (Parents, Julia)

Julia is a 30-year-old woman who has three school-going kids. While the kids are at school, Julia snacks pretty much the entire day and cooks dinner for the night. Lately, Julia has been eating plenty of unhealthy snacks so she decides to do something about it.

Task 1: Julia has heard some good things about a mobile phone application that helps people in improving their snacking habits. She downloads the application and has to set it up. Julia also tells her family about this phone application.

Task 2: After coming back from school, Julia's daughter offers her a candy cane, which she takes happily. In the evening Julia decides to use her new phone application to record her snack.

Task 3: The next day while watching TV in the evening, Julia grabs a bag of chips from her kitchen cabinet and remembers she should probably use the mobile phone application.

Task 4: The next day in the morning Julia grabs the pretzels jar to have it with her coffee. Julia uses her phone application in the evening.

Task 5: While using the phone application, Julia wonders what snacks she had been eating over the last few days.

Task 6: As suggested by the application, Julia gets some apples from her grocery store and eats them. By now, Julia has developed a habit of using the phone application every evening.

Task 7: Julia tries to keep having healthy snacks and eats bananas the next day.

Task 8: Almost a week has gone by since Julia has been using the phone application. She decides to see what she has been eating so far.

Task 9: While using the phone application, she remembers that she told her family about the application, so she compares her own snacking with her daughter Alice's snacking.

Task List for Mobile Phone Applications (Parents, Amna)

Amna is a 30-year-old woman who has three school-going kids. While the kids are at school, Amna snacks pretty much the entire day and cooks dinner for the night. Lately, Amna has been eating plenty of unhealthy snacks so she decides to do something about it.

Task 1: Amna has heard some good things about a mobile phone application that helps people in improving their snacking habits. She downloads the application and has to set it up. Amna also tells her family about this phone application.

Task 2: After coming back from school, Amna's daughter offers her a candy cane, which she takes happily. In the evening Amna decides to use her new phone application to record her snack.

Task 3: The next day while watching TV in the evening, Amna grabs a bag of chips from her kitchen cabinet and remembers she should probably use the mobile phone application.

Task 4: The next day in the morning Amna grabs the pretzels jar to have it with her coffee. Amna uses her phone application in the evening.

Task 5: While using the phone application, Amna wonders what snacks she had been eating over the last few days.

Task 6: As suggested by the application, Amna gets some apples from her grocery store and eats them. By now, Amna has developed a habit of using the phone application every evening.

Task 7: Amna tries to keep having healthy snacks and eats bananas the next day.

Task 8: Almost a week has gone by since Amna has been using the phone application. She decides to see what she has been eating so far.

Task 9: While using the phone application, she remembers that she told her family about the application, so she compares her own snacking with her son Ali's snacking.

Task List for Mobile Phone Applications (Parents, Ali)

Ali is a 30-year-old man who has three school-going kids. While the kids are at school, Ali snacks pretty much the entire day and cooks dinner for the night. Lately, Ali has been eating plenty of unhealthy snacks so he decides to do something about it.

Task 1: Ali has heard some good things about a mobile phone application that helps people in improving their snacking habits. He downloads the application and has to set it up. Ali also tells his family about this phone application.

Task 2: After coming back from school, Ali's daughter offers him a candy cane, which he takes happily. In the evening Ali decides to use his new phone application to record his snack.

Task 3: The next day while watching TV in the evening, Ali grabs a bag of chips from his kitchen cabinet and remembers he should probably use the mobile phone application.

Task 4: The next day in the morning Ali grabs the pretzels jar to have it with his coffee. Ali uses his phone application in the evening.

Task 5: While using the phone application, Ali wonders what snacks he had been eating over the last few days.

Task 6: As suggested by the application, Ali gets some apples from his grocery store and eats them. By now, Ali has developed a habit of using the phone application every evening.

Task 7: Ali tries to keep having healthy snacks and eats bananas the next day.

Task 8: Almost a week has gone by since Ali has been using the phone application. He decides to see what he has been eating so far.

Task 9: While using the phone application, he remembers that he told his family about the application, so he compares his own snacking with his daughter Amna's snacking.

Appendix E

Prototype Evaluation Mobile Application Questionnaire

1. Rank the applications from 1 (best) to 4 (worst)

Application	Rank
Snack Manager	
Lifespan Game	
Snack Educator	
Health Heroes	

2. How easy were the applications to use?

Application	Very Easy	Somewhat easy	Normal	Somewhat difficult	Very difficult
Snack Manager					
Lifespan Game					
Snack Educator					
Health Heroes					

3. How much fun was each application?

Application	A lot of fun	Somewhat fun	Normal	Somewhat boring	Very boring
Snack Manager					
Lifespan Game					
Snack Educator					
Health Heroes					

5. How likely are you to use each application for at least one month? Rate each application on a scale of 1 to 5:

1 - Least likely
2 – Less likely
3 – Average
4 – Somewhat likely
5 – Most likely

	Rating (1 - 5)
Snack Manager	
Lifespan Game	
Snack Educator	
Health Heroes	

5. How likely is your family to use each application for at least one month? Rate each application on a scale of 1 to 5:

1 - Least likely
2 – Less likely
3 – Average
4 – Somewhat likely
5 – Most likely

	Rating (1 - 5)
Snack Manager	
Lifespan Game	
Snack Educator	
Health Heroes	

6. Do you think the application to improve people's snacking habit should be:

a. **Gaming application**

b. **Non-gaming application**

c. **Both gaming and non-gaming**

7. What are the most important aspects of a mobile phone application that improves your snacking habits?

The mobile phone application should:

	Very important	Somewhat important	Neutral	Somewhat not important	Not important
educate people about good and bad foods					
be fun to use					
require minimal time to use					
be easy to use					
educate people about what are the effects of bad food on people's health					
provide goal setting options for motivation					
suggest healthy snacks					
provide snack price comparison between user's current snacks and the suggested healthier snacks					
track my snacking habits					
present my snacking habits					

provide the ability to message my family members about healthy snacking habits					
provide the ability to view the entire family's snacking habits					
provide multiple healthy snack choices					

Appendix F

Field Trial Background Questionnaire for Adults

The purpose of this questionnaire is to provide us with some background information about yourself, your family, and your experience with technology.

About You

Gender: _____

Age: _____

Race: _____

Ethnicity: White / Hispanic / African American / Other _____

Work Status: Not Working / Part-time / Full-time
If so what do you do? _____

Education: Primary School / Middle School / High School / College / Graduate Level

Your Family

How many children do you have? _____

For each child that you have, please enter their age and gender in the box provided below:

Age	Gender

If anyone else helps you look after your children, please state their relationship to you (e.g. sister, friend) and what they do to help in the box below:

Relationship	What they do to help

Technology

1. **Do you have a computer at home? Yes No**
   If so, how often do you use it?
   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

2. **Do you have access to a computer somewhere other than your home?**
   If so where? _____
   How often do you use it?
   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

3. **How much experience do you have using computers?**
    a. Less than 1 year
    b. 1-2 years
    c. 2-3 years
    d. 3-4 years
    e. 4-5 years
    f. More than 5 years

4. **Do you own a mobile phone?** **Yes** **No**
    If so, how often do you use it?
    a. Everyday
    b. A few times a week
    c. A few times a month
    d. A few times a year
    e. Not at all

5. **How much experience do you have using mobile phones?**
    a. Less 1 year
    b. 1-2 years
    c. 2-3 years
    d. 3-4 years
    e. 4-5 years
    f. More than 5 years

6. On a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the mobile phone for the following tasks (if you have never used a computer for a task, please check *never used)*.

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Make / Receive phone calls						
Send / Receive text messages						
Take photos						
Download applications						

Health Status

20. Would you say that in general your health is…
    a. Excellent
    b. Very good
    c. Good
    d. Fair
    e. Poor

21. Are there any foods that you cannot eat due to your health or beliefs?

_____

_____

22. Do you have any chronic illnesses? (i.e. diabetes, high blood pressure, or heart disease)

_____

_____

23. Do you have health insurance right now?

f. Yes
g. No
h. Not sure

24. IF YES TO QUESTION 23: Which of these is your main health insurance?

i. Medicare
j. Medicaid
k. I'm covered under my work insurance
l. I'm covered under my partner's plan where they work
m. I buy my own insurance
n. Other _____
o. I'm not sure

Appendix G

Field Trial Background Questionnaire for Teens

The purpose of this questionnaire is to provide us with some background information about yourself, your family, and your experience with technology.

About You

Gender: _____

Age: _____

Race: _____

Ethnicity: White / Hispanic / African American / Other _____

Work Status: Not Working / Part-time / Full-time
If so what do you do? _____

Education: Primary School / Middle School / High School / College / Graduate Level

Your Family

What tasks do your help your family complete around the household? (i.e. shopping for groceries, preparing meals, preparing snacks)

_____

_____

How many siblings do you have? _____

For each sibling that you have, please enter their age and gender in the box provided below:

Age	Boy/Girl

If anyone else helps you look after your siblings, please state their relationship to you (e.g. sister, friend) and what they do to help in the box below:

Relationship	What they do to help

<u>Technology</u>

1. **Do you have a computer at home? Yes No**
   If so, how often do you use it?
   a. Everyday
   b. A few times a week
   c. A few times a month
   d. A few times a year
   e. Not at all

2. **Do you have access to a computer somewhere other than your home?**
   If so where? _____
   How often do you use it?

a. Everyday
b. A few times a week
c. A few times a month
d. A few times a year
e. Not at all

3. **How much experience do you have using computers?**
    a. Less than 1 year
    b. 1-2 years
    c. 2-3 years
    d. 3-4 years
    e. 4-5 years
    f. More than 5 years

4. **Do you own a mobile phone?** **Yes** **No**
   If so, how often do you use it?
    a. Everyday
    b. A few times a week
    c. A few times a month
    d. A few times a year
    e. Not at all

5. **How much experience do you have using mobile phones?**
    a. Less 1 year
    b. 1-2 years
    c. 2-3 years
    d. 3-4 years
    e. 4-5 years
    f. More than 5 years

6. **One a scale of 1 to 5 with 1 being *no confidence at all* and 5 being *complete confidence*, please check how confident you are at using the mobile phone for the following tasks (if you have never used a computer for a task, please check *never used)*.**

	1 No Confidence	2	3 Some Confidence	4	5 Complete Confidence	Never Used
Make / Receive phone calls						
Send / Receive text messages						
Take photos						
Download applications (games, etc.)						

Health Status

20. Would you say that in general your health is…
    a. Excellent
    b. Very good
    c. Good
    d. Fair
    e. Poor

21. Are there any foods that you cannot eat due to your health or beliefs?

_____

_____

22. Do you have any chronic illnesses? (i.e. diabetes, high blood pressure, or heart disease)

_____

_____

23. Do you have health insurance right now?

f. Yes
g. No
h. Not sure

24. IF YES TO QUESTION 23: Which of these is your main health insurance?

i. Medicare
j. Medicaid
k. I'm covered under my work insurance
l. I'm covered under my spouse's plan where they work
m. I buy my own insurance
n. Other _____
o. I'm not sure

Appendix H

Field Trial Snack Healthiness and Awareness Questionnaire

1. **On a scale from 1 to 5, please mark how strongly you agree or disagree with the following statement:**

I am aware of the snacks I eat throughout my day.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

2. **On a scale from 1 to 5 please mark how strongly you agree or disagree with the following statement:**

I am aware of the snacks my family members eat throughout the day.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

3. **On a scale from 1 to 5 with 1 being *very unhealthy* and 5 being *very healthy*, please mark the answer that best completes the following sentence:**

The snacks that I normally eat are _____.

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

4. **On a scale from 1 to 5 with 1 being very unhealthy and 5 being very healthy, please mark the answer that best completes the following sentence:**

My family eats _____ *snacks.*

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

5. Fruits are available in my house.

1. never 2. rarely 3. Sometimes 4. Often 5. Unsure

6. Vegetables are available in my house.

1. never 2. rarely 3. Sometimes 4. Often 5. Unsure

7. The types of food I eat affect my health.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

8. The types of food I eat affect how I do in school or work.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

9. How much fruit do you think that you eat?

1. Very little 2. Little 3. Some 4. Much 5. Very much

10. Do you think that you eat more or less fruit than most people your age?

1. Much less 2. Less 3. The same 4. More 5. Much more

11. How many vegetables do you think that you eat?

1. Very few 2. Few 3. Some 4. Many 5. Very many

12. Do you think that you eat more or less vegetables than most people your age?

1. Much less 2. Less 3. The same 4. More 5. Much more

13. Please rate the following snacks based on how healthy you think that they are on a scale from 1 to 5 (1 being very unhealthy, 5 being very healthy):

a. Potato chips

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

b. Apples

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

c. Spicy Cheetos

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

d. Cookies

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

e. Broccoli

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very health

Appendix I

Field Trial 24-Hour Food Recall

1. **On a scale from 1 to 5, please mark how strongly you agree or disagree with the following statement:**

I am aware of the snacks I eat throughout my day.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

2. **On a scale from 1 to 5 please mark how strongly you agree or disagree with the following statement:**

I am aware of the snacks my family members eat throughout the day.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

3. **On a scale from 1 to 5 with 1 being *very unhealthy* and 5 being *very healthy*, please mark the answer that best completes the following sentence:**

The snacks that I normally eat are _____.

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

4. **On a scale from 1 to 5 with 1 being very unhealthy and 5 being very healthy, please mark the answer that best completes the following sentence:**

My family eats _____ *snacks.*

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

5. Fruits are available in my house.

1. never 2. rarely 3. Sometimes 4. Often 5. Unsure

6. Vegetables are available in my house.

1. never 2. rarely 3. Sometimes 4. Often 5. Unsure

7. The types of food I eat affect my health.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

8. The types of food I eat affect how I do in school or work.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

9. How much fruit do you think that you eat?

1. Very little 2. Little 3. Some 4. Much 5. Very much

10. Do you think that you eat more or less fruit than most people your age?

1. Much less 2. Less 3. The same 4. More 5. Much more

11. How many vegetables do you think that you eat?

1. Very few 2. Few 3. Some 4. Many 5. Very many

12. Do you think that you eat more or less vegetables than most people your age?

1. Much less 2. Less 3. The same 4. More 5. Much more

13. Please rate the following snacks based on how healthy you think that they are on a scale from 1 to 5 (1 being very unhealthy, 5 being very healthy):

a. Potato chips

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

b. Apples

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

c. Spicy Cheetos

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

d. Cookies

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very healthy

e. Broccoli

1. Very unhealthy 2. Unhealthy 3. Neither healthy/unhealthy 4. Healthy 5. Very health

Appendix J

Field Trial Meeting 4 Interview Guide

At the completion of 5-weeks of the intervention, we will conduct a 30-minute semi-structured interview with participants that use the application. The interview will be in part focused on getting feedback from them about the application. We will use the questions from the Application Evaluation as a starting guide for these interviews. These interviews will be semi-structured in nature, however below is an outline of the interview with a sense of the topics and questions we will ask.

We will ask participants about:

1. Their experience with the application
2. Problems they encountered while using the application
3. Their usage patterns with the application
4. Ways that participants see themselves using the application
5. Their health behaviors and snacking habits
6. Interactions with their family members surrounding snacking
7. Whether the application raised their awareness of their snacking habits?
8. Did the application raise awareness of their family's snacking habits?

Specific questions may include, but are not limited to:

1. Did you find the application useful? In what ways was it useful?

2. Is this application something you would want to continue using? How might you use this application in your everyday life?

3. Did you have any problems using the application? What kinds of problems did you encounter?

4. We noticed that you used the game interface most, what did you like about that interface? Describe how you moved through the game. Was it too fast, too slow, or just right?

4. We noticed you used the non-game interface the most, what did you like about that interface? Can you tell me about the stars in this interface? What do you think they

meant? How did you use the stars when making a decision about a snack? Did you like the stars?

5. What other features do you think would be helpful to have in an application like this?

6. Tell me about your snacking habits. How often do you eat snacks and what types of snacks do you eat? When do you typically eat snacks?

7. Did you talk to your family members about your snacking and about the snacking application? We noticed you didn't use the messaging, did you instead talk to them face to face?

8. Did you tell your friends about the snacking application? Did you show them the application? What was their reaction about it?

9. Did you learn anything unexpected about your snacking habits?

Appendix K

Field Trial Mobile Application Questionnaire

1. How easy was the application to use?

Very Easy	Somewhat easy	Normal	Somewhat difficult	Very difficult

2. How enjoyable was the application to use?

Very enjoyable	Enjoyable	Average	Unenjoyable	Very unenjoyable

3. Would you tell your friend about this application?

Yes No

4. On a scale from 1 to 5, with 1 being strongly disagree to 5 being strongly agree, how strongly do you agree or disagree with the following statement?

It took too long to enter a snack.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

4. On a scale from 1 to 5, with 1 being strongly disagree to 5 being strongly agree, how strongly do you agree or disagree with the following statement?

This application made me more aware of my snacking habits.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

5. On a scale from 1 to 5, with 1 being strongly disagree to 5 being strongly agree, how strongly do you agree or disagree with the following statement?

This application made me more aware of my family's snacking habits.

1. Strongly disagree 2. Disagree 3. Neither agree/disagree 4. Agree 5. Strongly agree

6. Overall, how useful was this application for you?

Very useful (1)	(2)	Somewhat useful (3)	(4)	Not useful (5)

7. How useful did you find the following features of the application? (If you did not use the feature, leave it blank)

	Very useful (1)	(2)	Somewhat useful (3)	(4)	Not useful (5)
Reviewing your family's snacks					
Family messaging					
Entering a snack					
Reviewing snack suggestions					
Creating a new snack					
Watching game animations					
Reviewing your previous snacks					
The star representation of snack healthiness					
Ability to switch between the game and non-game mode					