Approaches to Food Journaling on Mobile Devices

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[†]an egocentric imitation, actually

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Abstract

Approaches to Food Journaling on Mobile Devices

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This sample dissertation is an aid to students who are attempting to format their theses with LaTeX, a sophisticated text formatter widely available at the University of Washington and other institutions of higher learning.

- It describes the use of a specialized macro package developed specifically for thesis production at the University. The macros customize LaTeX for the correct thesis style, allowing the student to concentrate on the substance of his or her text.[1]
- It demonstrates the solutions to a variety of formatting challenges found in thesis production.
- It serves as a template for a real dissertation.

[1] See Appendix A to obtain the source to this thesis and the style file.

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The author wishes to express sincere appreciation to University of Washington, where he has had the opportunity to work with the TeX formatting system, and to the author of TeX, Donald Knuth, *il miglior fabbro*.

DEDICATION

to Mazzy Star and Alec Ivan.

Chapter 1

INTRODUCTION

Nothing here yet.

Chapter 2
BACKGROUND AND RELATED WORK

2.1 Background

2.1.1 Self-Monitoring for Health

Self-monitoring has been key to supporting lifestyle behavior changes necessary for treating cardiovascular disease, diabetes, cancer, and renal disease.

Electronic self-monitoring has advantages over pencil and paper self-monitoring.

Certain lifestyle behaviors can help to prevent disease as well as treat it.

Since many of the behavior changes relate to nutrition and dietary intake, much research focuses on this. However, nutrition literature demonstrates that brief monitoring of the behaviors can still be effective. The technology domain has not put much emphasis on investigating brief monitoring instruments.

Self-monitoring can help people make the behavior changes that prevent disease.

2.1.2 Evaluation of Electronic Self-Monitoring

In this section, I'll talk about the evaluations of mobile devices for self-monitoring of dietary intake. There are a couple of ways evaluations can be grouped. First, in terms of whether the evaluation is done in terms of technology (evaluating the technology, interface, or how people use it), or in terms nutrition/medical (evaluating the support it provides for dietary change). While there is a rich literature in the medical and nutrition community about the use of electronic self-monitoring to support dietary or physical activity behavior change, much of that focuses on whether a tool in general improves the self-monitoring process. In the technology literature, evaluations focus more on documenting the design process and whether the technology works in regards to the intended impact.

I haven't seen any work published that focuses on evaluating how different features of an electronic self-monitoring tool impact the ability of an individual to self-monitor over time.

2.1.2.1 Nutrition-Related work

We have the nutrition community, where most self-monitoring of dietary intake is done in conjunction with a larger program, for example, a weight loss program that provides a lot of support for individuals (including tech support, personalizing software, and providing timely, personalized feedback on a regular basis). I specifically do not include or address research focused on the use of electronic self-monitoring to monitor disease conditions such as diabetes. The other concern of nutritionists is the task of collecting detailed information about a population's dietary intake to analyze it in terms of a number of variables (either descriptively, or to identify correlations between dietary factors and disease). Related research also includes work that is investigating how particular dietary changes impact disease; in this case, participants are required to self-monitor their dietary intake in order to confirm that they are following specific, prescribed nutritional goals. Researchers report on how different forms of self-monitoring support this larger research program.

In the weight loss program research, research reporting on self-monitoring of dietary intake consists of studies where people participating in an existing weight loss/management program use electronic self-monitoring. Participants are already participating in a successful program consisting of education, group meetings on a weekly/regular basis, and regular, personalized feedback. In these studies, participants who do use electronic self-monitoring adhere to the program better/longer, and tend to lose more weight than participants who aren't self-monitoring. Research in this area characteristically reports large number of participants monitoring for a long period of time.

In the case of gathering detailed information about dietary intake for epidemiological purposes, the goal is to collect very correct data. The concern in this case is that the longer the time between eating and documenting, the greater the chance of error in the record. Therefore, the researchers want very timely records to improve the quality of the data. However, the populations are generally less motivated to document their food intake. It's also possible that the populations are less nutritionally literate, and usually don't have extensive training in the use of the monitoring instruments. Research that fits this profile tends to collect dietary intake information on the scale of a few days, rather than weeks. This puts the participants at a disadvantage, as dietary intake instruments usually require a few days (at least) to become familiar, and personalization or customization of the instrument doesn't result in much benefit. Research in this area characteristically reports many participants tracking for a short period of time (3-7 days).

The final group of nutrition oriented research is concerned with the impact of various dietary recommendations over a long term. The Women's Health Initiative is an example. The Women's Health Initiative is tasked with studying the incidence of disease in women who have committed to following particular dietary guidelines, specifically low fat with high fruit, vegetable and whole grain intake. Women in this study need to document what they eat to provide verification to the program that they are following the diet. Here, the primary focus of the research is to support the participating women in following the diet, therefore the research program provides substantial resources and support to the participants, and additionally, the participants are highly motivated. Electronic self-monitoring has been studied in the context of making the recording process easier. Research in this area has the characteristics of large numbers of participants self-monitoring for a long period of time (1-6 months).

In all of the above mentioned research, the self-monitoring instruments are frequently commercially available software, and when instruments are developed for the work, they are rarely described in detail.

2.1.2.2 Technology-oriented work

In the technology-oriented domain, research focuses more on the design and development of technologies to support new self-monitoring technologies, or architecture to support self-monitoring. I am restricting this discussion to work related to the mobile self-monitoring of dietary intake, although sometimes the work includes related behaviors such as physical activity or overall wellness. This discussion specifically excludes work that includes only a web-based component.

One body of work in the technology areas focuses primarily on understanding specific populations, such as individuals with diabetes or renal disease, and mobile information needs specific to these populations. This includes both characteristics of the population (for example, renal disease sufferers tend to be older, etc) and the disease or treatment of the disease (for example, renal disease impacts eyesite and requires certain dietary restrictions). While these characteristics don't always pertain to a general population not suffering from these diseases, some insights that result from the tool design and evaluation do make sense.

Published evaluations of mobile/electronic self-monitoring of dietary intake tools vary widely. HyperFit papers report 4 different evaluations, ranging from being used by individuals, to weight loss support groups, and by nutrition coaches, either by themselves or by clients. Most evaluations are 2-4 weeks, with a notable exception of WellnessDiary, which was used for 3 months by a population of people who wanted to lose weight.

Apart from the work that focuses on a specific population, research in the technology domain mostly includes participants who are using the self-monitoring technology on their own. The population is frequently described as "overweight individuals who want to lose weight", and sometimes an education component is included, but for the most part, the study only looks at the use of the self-monitoring technology. This differs from the nutrition-oriented research that frequently has a substantial education and support component.

One of the main differences we see between evaluations published in the nutrition versus technology domains is that

One similarity we see in all of this work is that the process to capture detailed food and exercise records is frequently reported as "too difficult". This is partly due to general tediousness of creating entries, but partly due to the databases.

Database size ranges from non-existent ([] uses a triage approach, specifying whether a meal is healthy/unhealthy/unknown, while [] uses a 43-item survey to determine vegetable and whole grain intake) to very large (40,000-50,000). However, in all related work (except [sapofitness] which does not include detailed information about the evaluation or database), it is noted that participants found it difficult to find or enter food into the system. Two systems reported “pre-populating” the mobile database with user-specified common foods, but participants still encountered foods not in the system.

Evaluations also vary widely as to whether participants carry their own device and install the software, versus being provided a device by the study. In the technology-oriented research, it is more common for participants to install the software on their own personal device, while in the nutrition studies devices are frequently provided. It may be more common for technology studies to provide the software for personal devices primarily because the research is more recent, and the availability of personally owned devices suitable for such software has increased substantially recently. This field may be more aware of good practices for ubiquitous computing evaluations. The nutrition literature, however, has been investigating this line of research for longer, and began when mobile devices were not as common in study populations. Additionally, for the research that is high impact, it may be important that everyone has the same software, which until recently has required very specific hardware. Also, for studies with many participants self-monitoring for a short time period, it is reasonable for the study to have a few devices for all participants to share.

Reporting of measures varies depending on the goal and phase of the project. It would be helpful to be able to compare from study to study how the participants were using the software, to put it all in perspective. Usually an overall number is given: mean number of records per day. Sometimes rather than records, the number is the number of “compliant” days, or days when there are records entered at 3 different times. Usually there is a measure of adherence over time: the number of entered versus expected entries overall, as well as for the first week and the last week.

Opportunity to systematically evaluate dietary self-tracking with food databases?

2.2 Related Work

Chapter 3

CONTRIBUTION 1 BALANCE

3.1 Introduction

Globally, 34% of adults were overweight or obese in 2008 [130]. While this has been a concern particularly in Westernized countries, the epidemic is spreading globally: Nauru in the Oceania reported the greatest gain in BMI globally [69]. Overweight and obesity are major risk factors for cardiovascular disease (CVD), Type 2 diabetes mellitus, and certain forms of cancer [87] [40].

Self-monitoring, defined as the process of observing and recording target behavior, has been identified as a key component of behavior change in general [119] and for weight loss in particular [183] [35]. Of the people who have lost weight and kept it off (as registered with the Weight Loss Registry), the key behavior that correlates highly with losing and keeping weight off is the practice of self-monitoring both food (energy) intake and physical activity (energy expenditure) [ref]. In general, people tend to underestimate their energy intake, while overestimating how many calories they burn in physical activity (energy expenditure) [ref]. This tendency results in an unawareness of the actual overall balance of caloric intake and expenditure, which results in weight gain.

People underestimate energy intake for a variety of reasons, including a lack of awareness of how many calories are in food [ref]; what an appropriate serving size is [ref]; erroneous estimates of how much of a food has been eaten [ref]; and neglecting to consider calorie dense condiments or additions to a food [ref]. This effect is magnified when a person does not document what they eat as soon as they eat it, and time passes between consumption and recording [ref]. Additionally, although reflecting on food intake in the past (e.g., earlier in the day) may help raise an individual's awareness of calories in given foods, it does not enable them to make good decisions in the moment. Timely access to calorie data could help people not only capture and understand how many calories they have already consumed for the day, but also make better decisions going forward.

People also underestimate the number of calories they burn over time. An estimate of energy expenditure by a person in a given time period is the sum of three items: the base metabolism for that individual (how many calories their body consumes for basic bodily function), the amount and intensity of intentional exercise (e.g., going for a run) and the amount and intensity of unintentional exercise (e.g., how much walking versus sitting a person does). It is relatively easy for people to measure their intentional exercise, as it's usually well-defined. However, humans tend to vastly underestimate their unintentional exercise [ref]. Readily available technology such as wearable sensors can keep track of general activity for an individual, allowing them to more closely track energy expenditure over time.

The BALANCE project was a multi-year, interdisciplinary project with the goal of designing, building, and evaluating a mobile-phone based application to help people overcome these challenges of tracking their overall balance of energy intake and expenditure. It combines a wearable device that calculates caloric expenditure with a mobile phone that runs software that includes a food diary to track caloric intake. The software also includes a visualization that reports the real-time energy balance for the day. The wearable device is built using the multi-sensor board (MSB) [ref]. The MSB contains an accelerometer, now standard in mobile phones, as well as other sensors that aide in physical activity detection.

The software consisted of three main components: a "fuel gauge" visualization that reflects the current caloric balance; a food diary; and a physical activity diary. The food diary requires users to enter the details of what they eat, while the physical activity diary accepts input from the external MSB device that calculates most calories burned from physical activity (the exception being water or high-impact sports, which need to be manually entered).

3.1.1 Project Overview

This project consisted of many phases and many people were involved. We started with brainstorming designs for and evaluation of the fuel-gauge visualization; executed a paper prototype evaluation of the software based on specified need, goals and reviews of similar tools; built an initial prototype on a feature phone platform; validated the algorithms on the MSB for calculating calorie expenditure; and executed an iterative design and implementation process of the application on a smartphone. Finally, the smartphone software and MSB were combined and validated overall. My primary contribution to this project was the design and implementation of the smartphone software. The rest of this chapter describes the process and final product in further detail.

Multiple documents describe contributions to the BALANCE project. Tamara Denning contributed to the initial design and paper prototype evaluations [ref]. Deonna Hughes designed, conducted, and analyzed the focus groups and prototype iterations [ref, ref]. She looked at two metrics for improvement from iteration to iteration. The first was the result of standardized usability questionnaires (CSUQ [ref] and MPUQ [ref]); the other was the time between when participants ate a food and when they entered it in the diary. Neither metric showed significant improvement in the prototype over 5 iterations. I discuss this in further detail later in this chapter. Jonathan Lester designed and evaluated the calorie expenditure algorithms [ref, ref], employing a gold-standard oxygen-consumption evaluation methodology. Algorithms using the MSB sensor data were 89.54% (+/- 7.25%) accurate in the lab and 79.8% (+/- 9.48%) in the field. Heather Snively designed and conducted the overall system validation [ref, ref]. Participants used the entire system for 4 days, tracking their food intake on days 1, 3, and 4. On day 2 participants provided a 24-hr recall of what they ate on day 1, which was compared to entries in the food diary on the first day. The average percent calorie difference between the mobile phone food diary and the 24-hr recall was 9 +/- 18% [ref].

3.2 Fuel-Gauge Visualization

The goal of the BALANCE project was to combine a food diary to collect information about energy intake, a physical activity component (diary + MSB) to collect energy expenditure information, and the fuel gauge visualization to show the current energy balance throughout the day. The heart of the system was a unifying user interface on a mobile phone.

The first investigation focused on the fuel-gauge visualization. It was important that the visualization provide the current overall energy balance, but it was unclear what other information would be necessary or relevant. Additionally, it was important to produce a visualization that was understandable at a glance, provided more meaning upon reflection, and worked within the constraints of the target device in terms of size and resolution. One concern was the level of abstraction: whether the visualization depicts a concrete, physical world phenomena or a more mathematically-oriented graph view. In this section, I describe a user study to collect feedback on a wide range of potential visualizations.

3.2.1 Participants

12 participants (10 female and 2 male) were recruited from a university community. Ages ranged from 18-50, with a majority (8) in the 30-40 year age range.

3.2.2 Procedure

Participants were asked to come to the lab, where they filled out a survey collecting basic demographic information. Next, the interviewer conducted a survey where participants were asked to rate the desirability of given features for food and exercise applications on a mobile phone and to talk about what they had already eaten that day (or the previous day, depending on time of interview), including context (what they ate, how much, where, when, and how much that meal varies for them).

Next, participants were shown the different visualizations. Each visualization depicted the same four situations: the start of the day, before any food is entered or calories expended; the end of the day, when more than the day's goal had been consumed and expended; and two points in between, showing various balance levels.

There were two categories: graphs (two total) and visualizations (five total). Participants were asked to rank their preferred visualizations within each category and offer comments.

3.2.3 *Instruments*

The team brainstormed seven candidate visualizations. Ideas ranged from abstract charts to concrete metaphors. Previous work investigates the value of having abstract versus concrete representations [ref], so we aimed for a wide range at this point in the design process.

The main goal of the visualization is to depict the current energy intake/expenditure balance. Other pieces of information that could be helpful included:

1. what the goal calorie expenditure and intake is for a current day;

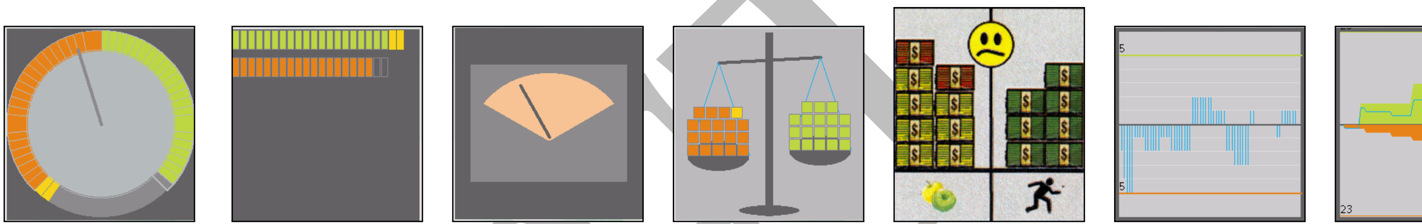
2. progress toward that goal/target over the course of the day; and

3. whether or how much the user was over the intake or expenditure goal for the day.

Mobile phone displays vary greatly in their capabilities, specifically in size and resolution. To present the visualizations in the context that they would appear to users, the visualizations were generated on the mobile phone device, saved as screenshots, then printed on paper. It was important that the visualizations reflect the constraints of the display, as well as the fact that these were early sketches. Presenting the visualizations on the actual mobile device could raise user expectations of the visualization, while paper prototypes and screenshots help to restrain user expectations appropriately. The visualizations were deliberately "rough" and unrefined, to target the level of refinement ideal for a paper prototype.

3.2.4 *Results and Discussion*

We rated visualizations based on the number of #1 rankings it received. In the graph section, we saw that participants strongly preferred Graph 2, giving it 10 #1 rankings. However, feedback overall was that the graphs were challenging to understand at a glance, and needed more explanation. In the visualization section, 5 participants ranked Viz1 #1, making it clearly preferred. Participants liked the "meter", and the comparison it provided (P2). It was also remarked to be "clear, straightforward", that it "seems useful" and "shows



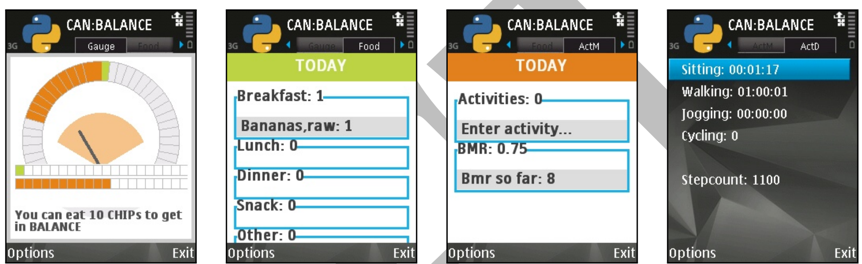
(a) Viz1 (b) Viz2 (c) Viz3 (d) Viz4 (e) Viz5 (f) Graph1 (g) G

Figure 3.1: A bunch of screens. Look at subfig and continueFloat to help wrap some of the images to the next line.

a good balance [of detail]" (P5). Viz 3 received all #4 and #5 rankings, because it "doesn't show progress and amounts" (P12), and is "more confusing" (P7) . Viz 5 received a wider range of rankings, the feedback on it was strong (it's "a little too judgmental", and "not neutral enough" [P3];P5: "means nothing with respect to food, smileys are annoying"; P2: "faces are more discouraging than encouraging-critique").

Feedback from the user population indicated that Viz1 is the preferred visualization. Participants liked that it showed the current energy balance while also showing progress towards daily goals or targets, for both energy intake and expenditure. Feedback indicates that the most simple feedback shown (direction and magnitude of energy imbalance, Viz3) does not show enough information and is unsatisfying. Participants in general found the time-based visualizations too complicated to quickly understand, and didn't believe that the balance over time was useful information.

Feedback also indicated that participants felt the physical metaphors such as the scales depicted in Viz4 and Viz5 were symbols that were too rich and the imagery too loaded for simple feedback. The scale metaphor reminded users that if their energy balance was off, their own scale would be tipping. Users were vocal against the use of money to represent caloric intake and expenditure. While the money "earned versus spent" metaphor could be powerful to communicate the "calories in equals calories out" concept, people reported that both money and weight were too emotionally charged and they didn't want to put the two together. The smiley faces in Viz5, while encouraging when the user is doing well, can



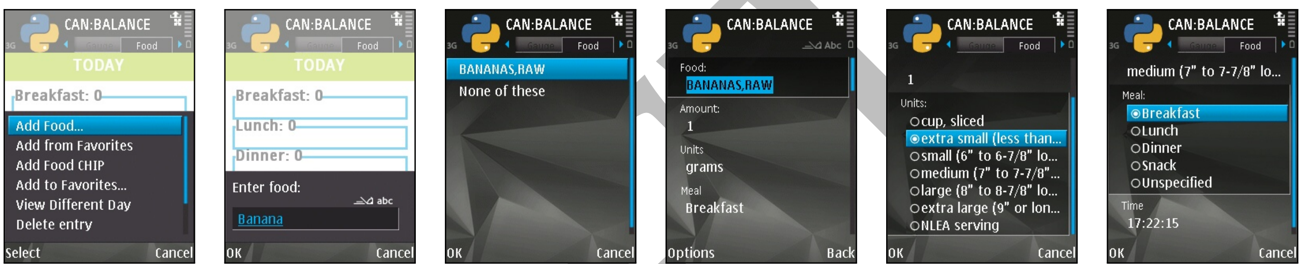
(a) (b) (c) (d)

Figure 3.2: Nokia prototype main screens

be discouraging when the user is struggling. Indeed, this is consistent with [ref], which explores communicating positive and negative affect in feedback mechanisms.

3.3 *Prototype, V1 (Feature Phone & USDA Food Database)*

The next phase of the BALANCE project was the design and development of the first mobile phone prototype. The design of this prototype was informed by a review of existing related products (to identify key desired features), a paper prototype process, and the visualization feedback process described above. This prototype was built on the Symbian S60 feature phone platform (a top-of-the-line mobile phone platform at the time). Characteristics of mobile phones running the Symbian S60 platform included a relatively powerful processor and ample storage, the ability to develop and run custom software, and high quality cameras, but had a small display and 12-key keypads. This prototype was built with the commonly used, freely available USDA food database (SR21) [ref]. The database schema is in [ref]. Additionally, we added an index based on the FOOD_DES.FoodName column. User search requests were turned into a wildcard LIKE query against the index. Multiple words in the user request were split ANDed together.



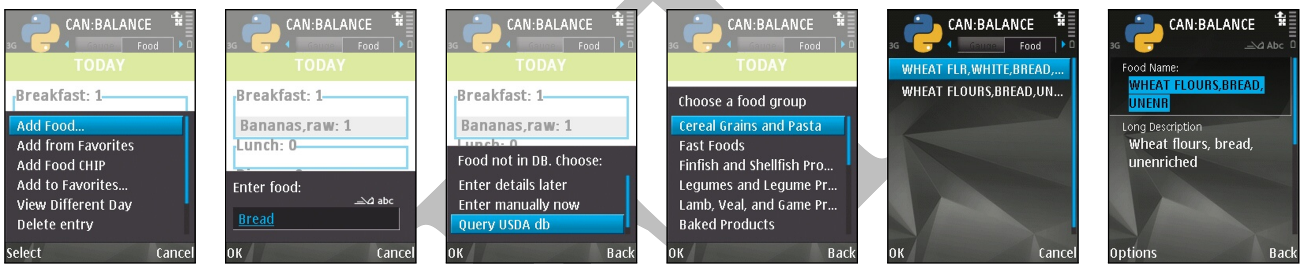
(a) (b) (c) (d) (e) (f)

Figure 3.3: Nokia prototype: Add known food

3.3.1 Description

The BALANCE software consisted of four main screens (Figure 3): The overall balance visualization (a), the food diary that shows which foods have been entered today (b), and two activity screens. The first activity screen (c) shows intentional activity that is not detected by the MSB (for example, water sports such as swimming) and is therefore entered by the user, and energy expenditure due to base metabolic rate (BMR-the calories a body uses for basic metabolic processes like breathing). The second activity screen (d) shows activity detected by the MSB unit, and its contribution to overall energy expenditure. We adopted an overall simplifying construct for calorie counting called "CHIPs": [acronym here][ref]. A CHIP is simply a unit of 100 calories. Humans find it easier to count and keep track of larger increments (smaller numbers), so in the BALANCE software, all calorie counts are reported in CHIPs, both for intake and expenditure.

Above (Figure 4), the screens depict the process of adding "Banana" to today's food diary. The user first selects "Add Food" from the menu, types in the term using T9 or multitap, and on submit, a list of foods that the user has entered before is shown. The user selects "Banana, Raw", and is shown a screen to modify the amounts and any timing information. By default, the USDA database has serving sizes in grams. Some entries have alternate serving sizes available. For "Banana, Raw", the serving sizes include "cup, sliced" and "small (6" to 6 7/8" long).



(a) (b) (c) (d) (e) (f)

Figure 3.4: Nokia prototype: Adding newly encountered (previously unused) food

One primary goal for this project was for users to be able to quickly and accurately enter exactly how many calories they had consumed. This required finding the most appropriate, exact food and entering it in the exact amount, right after eating it. The process of finding food had to happen quickly to minimize interruption to the user. Queries to the entire food database took a long time to execute (this is described in further detail later), so to improve performance we separated the database into two separate databases: the entire USDA database and foods the user has entered before. The second database ("personal db") reflects that many people have a relatively small number of foods they eat on a regular basis [ref]. When the user submits a search, the app first checks the personal db, which is fast because it's small. If there are no results, the user is asked whether they want to "enter later", "enter manually", or "look up in USDA db". The first option allows the user to bookmark the entry, since both the manual entry and USDA lookup are time consuming. The "enter manually" option provides a form for the user to make an entry based on the Nutrition Information panel required to be printed on all packaged foods.

Figure 5 shows the process of entering a food ("bread") that has not been used before; therefore it doesn't exist in the personal database. When "bread" is not found in the database, the user is given the option to look it up in the USDA database. When the query returns and contains foods that belong in more than one food group, it first lists the food groups to narrow down the list of possible choices. In this case, a search for "bread" resulted in foods in 14 food groups, and 3 pages of choices. Once the user chooses "Cereal

Grains and Pasta”, they can then choose the bread they ate, they can modify the name or details, and it is added to the personal database. The user can then specify the details needed to add it to the food diary.

3.3.2 *Database Optimization and Querying*

One of the challenges of building dietary intake-tracking tools is identifying what kind of queries the user will make, what they expect the results to be, and generating a database query that provides the expected results from the nutrition database.

Generating a query based on user input has performance implications, particularly when working with text. Queries on a string column are slower than other data types, and searching for strings with wildcards further degrades the response time.

In the BALANCE software, a user provides a basic query, and the software generates a query based on that user input. Each word the user provides becomes a predicate in the query. This approach results in queries that are known to have poor performance, but this is necessary to account for the ordering of relevant terms in the database. Table [ref] gives some examples of food terms that a user might enter, and some example entries in the database.

Table 3.1: Add caption

User Search Request	**Query WHERE clause**	**Example matches from database**
cheese	LIKE *cheese*	Cheese, Cheddar Cheese, Cream Bagel with Cream Cheese Pizza, Cheese and Pepperoni
cream cheese	LIKE *cream* AND LIKE *cheese*	Cheese, Cream Bagel with Cream Cheese

3.3.3 *Observations*

The first prototype of the BALANCE software helped us to identify unanticipated difficulties. In this section, I describe the problems we observed. The problems generally relate to the process of finding and choosing a food for the food diary. A summary list is shown below, and I further describe each one:

1. Text entry was too hard with 12-key keypad.
2. It took too long to search due to poor db performance.
3. It was difficult to find and choose a specific food.
   - Using Food Class to filter search results.
   - Long names that didn't fit on the screen.
   - No entry for commonly prepared foods.
   - For some foods, many variations to choose from.

3.3.3.1 *Text Entry Was Too Hard*

The 12-key keypad required users to use multi-tap or T9 to enter the names of food they have eaten. This is very difficult to do for foods with long names. The decision users encountered every time they wanted to enter a food was whether to commit to typing in a long, detailed food name that is likely to generate fewer food choices to choose from, or type in a short food name which resulted in many responses.

Recommendation: To appeal to less tech-savvy consumers, provide a more comfortable means of text input.

3.3.3.2 *Too Long To Search*

As discussed above, user input is converted into a query that is known to have poor performance. This is partly due to a mismatch between what the user wants to search for ("cream cheese") and how it may be stored in the database ("cheese, cream" or "bagel, with cream cheese"). It's important that the software returns all of the results.

This concern is primarily due to the limited resources on the mobile phone. The database available on the mobile platform has reduced capabilities as compared to those available on a desktop or in a high performance computing environment, and the limited processing power of the device magnifies the limitations of the database.

Recommendation: Faster hardware, improve the filtering process.

3.3.3.3 It Was Difficult To Find And Choose A Food

After entering a food query and waiting for the search to return, a user needs to choose the desired food from all of the results. Using Food Class to filter search results. As noted earlier, if the results are from just one Food Class, the entire list of results is immediately shown. If there are results in multiple Food Classes, the list of Food Classes is shown to allow the user to choose the most appropriate. To find the target food, the user must choose from a potentially long list of Food Classes (the results for the query “Bread” include 16 Food Classes). Some of the food classes are difficult to distinguish. For example, the Food Classes for “Bread” includes both “Cereal Grains and Pasta” and “Baked Goods”. This requires the user to make a decision, and users unfamiliar with the Food Classes aren’t sure which to choose.

Recommendation: Don’t force the user to think about arbitrary Food Classes. Provide guidance about what each Food Class represents. Provide some “teasers” or a few items of that Food Class to demonstrate what kinds of foods it contains.

3.3.3.3.1 Long names don’t fit on the screen. The USDA database contains food descriptions that are long and descriptive. For example, a typical entry for the query “Steak” is “Beef, short loin, porterhouse steak, separable lean and fat, trimmed to 1/4” fat, USDA choice, raw”. The alternative “short” description is a similar entry using defined abbreviations: “Beef, shrt loin,prtrhs steak,ln,1/4” fat,usda choic,raw”. Neither of these descriptions display well on the small screen size of the target device. If they are displayed one entry per line in a font that is comfortable to read, not enough words are shown to distinguish one entry from another. If the description is shown on multiple lines, only one or two entries can be shown at a time. Forcing the user to select one to see more detail and

Figure 3.5: Nokia prototype: 'Steak' results

then returning to the list screen is time consuming and frustrating.

Recommendation: Use a larger display with higher resolution. Use a database that has more useful short descriptions. Structure the database to provide a short "food name", a short description, and a detailed description. No entries for common prepared foods. One of the drawbacks of the USDA database is that it did not include many prepared foods, such as those purchased at a grocery store or restaurant. The database contains food entries from only 60 manufacturers, which include some of the major food manufacturers in the US (Burger King, Kellogg, Nestle, McDonalds). However, users expect that if they can purchase a food (ie, it has a UPC code), then it will be in the database.

Recommendation: Choose a database that includes a more comprehensive list of prepared foods.

For some foods, many items to choose from. For some foods, there are many entries. For example, a query for "Cheese" in the "Dairy and Egg Products" Food Class has 44 entries. The cheese entries are somewhat reasonable: blue, brick, brie, camembert, caraway, cheddar, etc. Some may be unfamiliar to a user, but they are clearly different and possibly significantly different. The results for "Porterhouse" (steak) are not so clearly different, however:

- Beef, short loin, porterhouse steak, separable lean and fat, trimmed to 0" fat, all grades, cooked, broiled
- Beef, short loin, porterhouse steak, separable lean and fat, trimmed to 0" fat, USDA choice, cooked, broiled

- Beef, short loin, porterhouse steak, separable lean and fat, trimmed to 0″ fat, USDA select, cooked, broiled
- Beef, short loin, porterhouse steak, separable lean only, trimmed to 0″ fat, all grades, cooked, broiled
- Beef, short loin, porterhouse steak, separable lean only, trimmed to 0″ fat, USDA choice, cooked, broiled
- Beef, short loin, porterhouse steak, separable lean only, trimmed to 0″ fat, USDA select, cooked, broiled

Users are confused about how to choose which one they should enter, and wonder whether the difference between all these entries really matters. Additionally, the amount of distinguishing detail for this entry makes them wonder if they should be capturing that amount of detail for all of the foods they enter. This compounds the previous problem of not being able to find prepared foods.

Recommendation: **U**se a database that was designed for use by a consumer rather than an expert.

Overall, the process to add food to the food diary is just too long, due to all of the factors described in detail above. For the BALANCE project, it was important that users are able to enter foods quickly, so that they are able to enter food throughout the day and ensure the fuel-gauge visualization is properly updated.

3.3.4 Discussion

This prototype experience made us more aware of the inherent challenges around designing and developing a food diary for a mobile phone. The challenges are due partly to the database, and partly from using a device with limited interaction modes to navigate a challenging data environment. The population we were targeting is a general population, not necessarily very comfortable entering text via multitap/T9; the challenge of text entry magnifies the problem of querying the database and navigating the results.

One conclusion from this process was to use a different mobile phone. The original Symbian S60 device was much friendlier to use and more powerful than previous smartphones, but the general population had not yet much experience with smartphones, and this was the target population for the project. Text entry was one of the biggest barriers: the 12-key keypad with multitap or T9 input was not comfortable to most consumers.

The database negatively impacted the navigation and performance. Database entries were not well suited to the mobile phone display, and the query process on the device was too slow to be acceptable. It is also necessary to have more popularly available packaged/prepared foods, although some of the closely related foods could be collapsed. The importance of the database in self-monitoring or dietary assessment is outlined in [ref][Stumbo08]. Indeed, they state "Mastery of computerized dietary assessment requires an understanding of the database in terms of the naming conventions, the search strategy for finding foods, and data completeness for generic and brand-name foods." This is consistent with our experiences.

3.4 Food Databases

There are conflicting requirements for the food database. The database needs to be quick to search (small), yet have the foods that people eat and are looking for (complete/large). It also needs to be able to distinguish between similar items, and use terminology that is familiar to the target user population. Grouping into friendly and familiar food groups or classes will help users to find food in the database by providing data to filter on or browse. Providing useful, appropriate serving sizes is another helpful feature. For example, Coca Cola should have commonly available serving sizes to choose from, such as a 12-oz can, a 20-oz bottle, or a 16-oz cup, even if the typical/official serving size is 8 oz.

The history of food databases might be helpful in understanding the characteristics of the databases. Generally, food databases are used by professionals, experts in food service, preparation, and evaluation. Hospitals, nursing homes, and other medical facilities use food databases to make sure that patients are fed properly, within the constraints they might have. They generate menus for days, weeks and months, using the database to ensure proper nutrition for all recipients. Nutritionists and registered dieticians use commercial food databases to work with clients who have certain dietary constraints-either to look up foods that an individual ate and evaluate their diet overall, or to generate a meal plan for an individual and provide detailed information about it. Organizations such as daycares, schools and prisons (especially those that get government funding) use the food databases to ensure that they meet governmental guidelines. Food manufacturers use food databases to generate Nutrition Facts labels for their products.

For the tasks I've outlined above, the end user of the database is an expert who is familiar with food systems, organization, and terminology. The user has been trained, and uses the database on a regular basis. Increasingly, food databases have been made available to the general population, usually in the form of a consumer tool.

Table 2 provides some information on two databases: the USDA (SR21) database we used for the first prototype, and the NutritionistPro Knowledge Base that we used for the next version of the software.

Table 3.2: Comparing nutrition databases

	USDA	**NutritionistPro Knowledge Base**
Version	SR21 (Sept 2008)	V44 (Fall, 2009)
File Size (Access db)	16.5Mb	135Mb
Number of foods	7,412	39,194
Number of food servings (types?)	13,087 (num records in the Weight table)	46,722 (num records in tblFoodServingTypes)
Number of unique serving type descriptions	1700	5087
Number of Manufacturers	60	592
Num Recipes		783
Food Groups	24	369 (Food Classeshierarchical)
Number of nutrients	140	90

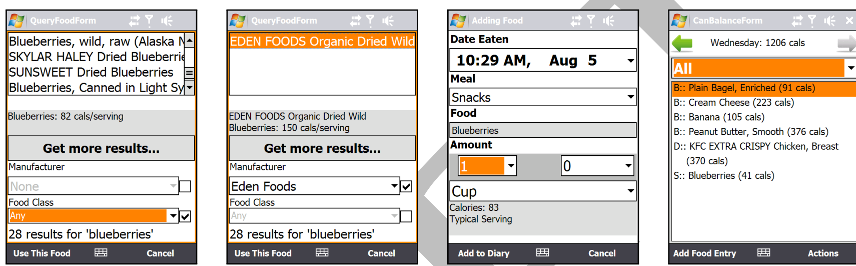
3.5 Food Diary: Iterative Design And Evaluation

In this section, I describe the design and features of the food diary portion of the overall BALANCE project. The challenges identified in the previous section informed the decision to move to a Windows Mobile platform and adopt a commercially available nutrition database to drive the food diary. The combination of the paper prototype user study and Symbian implementation informed the new design on the Windows Mobile platform, and the final design was informed by an iterative, user-centered evaluation process.

Focus groups of 4-5 participants provided user feedback in the design and development process. We convened 5 focus groups over a 7 month period. Participants were given a mobile phone running the food diary software, and asked to track what they eat for three days prior to the focus group. After the three days of tracking and before the focus group, participants were asked to complete 2 usability questionnaires (CSUQ and MPUQ, [ref]). The focus group was moderated by a team member, and topics focused on what the participants liked, what worked and didn't work, and features they would like to see added. Details are in Appendix [ref]. Feedback from the participants in the focus groups provided input to the design and development of the next software iteration. We used two metrics to evaluate the overall progress of the iterative process. First, we analyzed usability questionnaire responses over time. These did not show a significant improvement of the usability of the food diary software overall. The other measure of progress we considered was the time between when a participant ate a food, and when they entered it in the food diary. We hypothesized that this time would decrease as the food diary improved. This also did not show a significant improvement of the food diary. Details of the analysis are provided in [ref], and I discuss the use of these metrics later in this section, as well as in Chapter [x] [ref].

3.5.1 Overall Design

The final version of the BALANCE software ran on a Windows Mobile 6.1 Professional device. We chose this device because it had a large display, a touch screen, and a slide-out QWERTY keyboard. Text input can be done either via the physical QWERTY keyboard or



(a) (b) (c) (d)

Figure 3.6: WinMobile Food diary

with the "soft input panel", on-screen keyboard. We used the NutritionistPro Knowledge Base for the food diary.

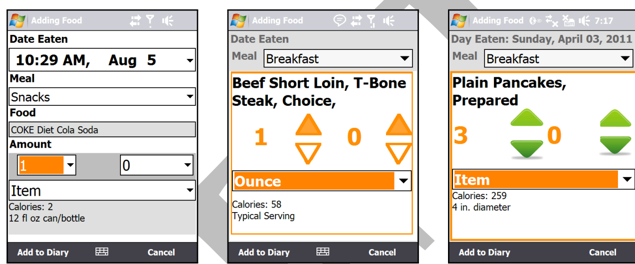
3.5.1.1 Food Diary Software

The primary task for this software is to enable users to find a food that they've eaten from a database, specify how much of it they ate, and save a record of it.

Figure 7 shows a walkthrough of the add food process. The application starts with a list of food that's been eaten today. The "Add Food" button displays a screen that allows the user to start typing an entry. As the user types, a list of common or recently eaten foods populates the display. If the user sees what they want, they can select it, or choose to "Enter Manually" (create a new entry based on the Nutrition Information label on the package), or "Find more", which searches the entire food database (a). This list can be filtered by manufacturer and food class (b). Once a food is selected, the user specifies what time they ate the food, which meal it should be counted with, and how much of it they ate (c). The entry is then saved and shown on the daily food list (d).

3.5.2 Selected Features and Feedback

Throughout the iterative design process, we aimed to improve the existing functionality and add features as necessary. In this section, I describe a couple of the features that



(a) (b) (c)

Figure 3.7: Evolution of serving size specification

evolved based on user feedback.

3.5.2.1 *Touch Friendly Screen Design*

One of the reasons we chose the final device was for its touch-sensitive screen. To improve the time it takes to create a food entry, the items on the screen were displayed big enough to be selected by a finger/fingernail. However, early in the feedback process, users reported that they didn't like the stylus-it was too small to hold comfortably, there was fear around losing it, and it was time consuming to take it out and put it back. Therefore, one change we made was to replace the traditional WinMobile UI widgets with custom graphical widgets that looked friendlier to touch. Users remarked on the "friendliness" and "cheeriness" of the new widgets.

3.5.2.2 *Create New Food Database Entry*

The NutritionistPro database contained many foods, but users still reported encountering foods that were not in the database. This resulted in the ability to add a new food to the database, using information from the Nutrition Facts label all packaged foods are required to have. After the entry is created, it shows up in the quick-search results with other common and recently used foods.

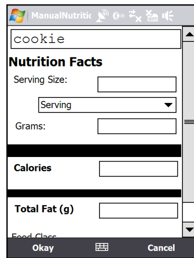
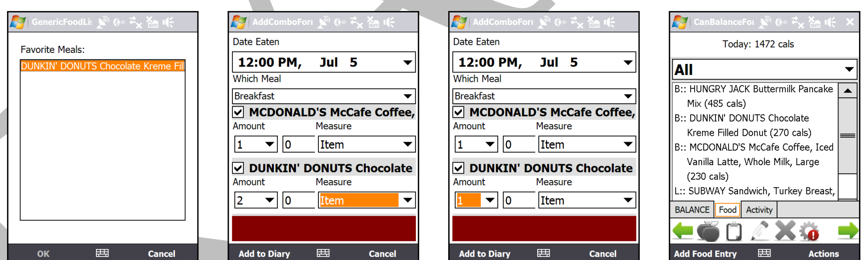


Figure 3.8: Add new entry (manual) to food diary



(a) (b) (c) (d)

Figure 3.9: Favorite meals walkthrough

3.5.2.3 *Favorite Meals*

Focus group participants repeatedly [ref] asked for the ability to bookmark favorite foods, and specify combinations that were commonly eaten together as a meal. We make a distinction between a recipe and a meal: A meal is a group of foods commonly eaten together, such as coffee and a donut, which might be a common order at one's favorite coffee shop, or the typical sandwich one makes for lunch. A recipe consists of a bunch of foods combined, usually to make multiple servings. For this version of the software, we did not implement the recipe-creation feature, but did implement the ability to specify favorite foods and meals, as shown below (Figure 10).

3.5.3 Database Query Details

Adopting the commercially available NutritionistPro database resulted in a much larger number of foods available to the user. While the USDA database had the user challenge of making it difficult to distinguish between many similar unprocessed foods and relatively few processed/manufactured foods, the NutritionistPro database had many more processed and manufactured foods to choose from, which users sometimes found overwhelming.

In this section, I describe some of the ways we tried to make the query process more user friendly. Rather than describe all the possible improvements we considered, I focus on the final implementation.

One weakness of the database supported on the Windows Mobile platform (Sql Server CE) is that it doesn't support full text search (FTS). When FTS is available on a database, queries can be made that reflect linguistic characteristics of a given language (such as English). With a FTS capability, one can easily query not just for a word or a phrase, but a word or a phrase that starts with given text (prefix), inflectional forms of a word (for example, foot or feet), a word or phrase close to another word or phrase, or a synonymous term. This is valuable in the case of food diaries, because from the user's perspective it's sometimes unclear whether the food diary will have "Potatoes, Mashed" or "Mashed Potatoes" as an entry. Additionally, consumers in general are familiar with search strategies that employed FTS, whether or not they know enough about it to specify it exactly. Users are able to articulate is that a particular search function "just knows what I'm looking for" and "does the right thing", linguistically-a search for "potatoes" also yields results with "potato".

In addition to the lack of linguistic support that FTS provides when searching text in a database, speed is a consideration. The alternative to FTS is a LIKE query based on character patterns. A LIKE query against millions of rows of text data can take minutes to return; whereas a FTS query can take only seconds or less against the same data, depending on the number of rows that are returned (due to the pre-built index).

We tried to overcome the lack of free-text search on the database by being smart about the queries we generated. However, the more complex a query became, the longer the time to respond, even if the results were "better". In general, our approach favored returning better results faster, rather than minimizing the size of the database. Storage was cheap: we could easily add a larger memory card to the device, but we couldn't improve the processor.

To improve the query time and search process, we implemented a "poor man's predictive search". As mentioned above, the system contained two food databases: the large, complete NutritionistPro database, and a smaller, personalized personal database. The personal database was initially seeded with foods marked as "common" or "generic" in the NutritionistPro database. To improve the responsiveness, there was a table in the personal database that contained the first 3 letters of all words in the food name, description and manufacturer name associated with a food entry. When the user starts typing to search for a food name, after 3 characters are entered, a results box is generated based on an exact string match from that table. As the user continues typing, the list of results is filtered based on that text. If a desired food is not found, the user can "Find More", which ends up performing the longer LIKE query on the NutritionistPro database. When a food is selected from the NutritionistPro database and entered into the food diary, it is also stored in the personal database, and the prefix table is updated. This adds time to the process, but this time is negligible to the time required for the NutritionistPro query.

3.5.4 Metrics

In this section, I want to talk about the metrics we used to guide the development and evaluation of the software. Specifically, I want to review what we used, how they worked, why they failed, and propose alternate metrics to collect during the final evaluation.

One way we attempted to quantify the success of the software by measuring the time between when a food was eaten and when it was entered into the diary. This metric didn't show any significant improvement, but it did highlight important information about how the software is used. In the focus group discussions, participants volunteered that they didn't enter food throughout the day, and weren't likely to. Multiple reasons were given for this: sometimes it was just that the person was too busy and couldn't take the time, and sometimes it was just easier to do it all at once later in the day. Some participants noted that they took advantage of [pockets of free time] such as when waiting at the bus to review and enter their food. This gives us some insight, but it's still unclear whether they won't enter it at the time because the software is bad, or if they won't enter it the time because it's an inherently tedious process, or due to external influences.

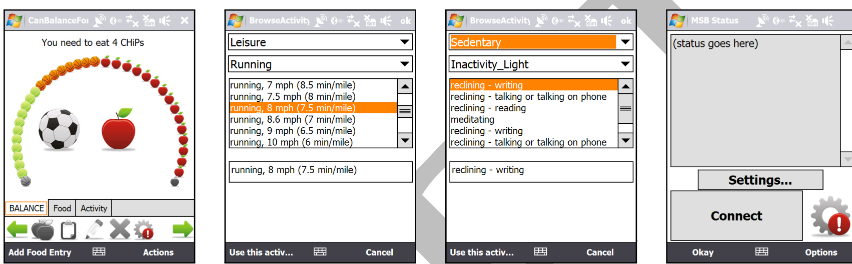
This experience highlighted the importance of identifying appropriate metrics for evaluating food diaries on cell phones, reflecting both usability/how the software is being used and domain success-whether people are able to achieve the stated goal (capturing the right number of calories by identifying all the foods one ate).

3.6 Validating BALANCE

The final BALANCE validation combined all key components of the project: the MSB device for calorie expenditure calculation and the mobile phone with the visualization, food diary and activity diary software. Participants were asked to carry the mobile phone and MSB for 4 days. They were asked to enter all food and drink consumed (except water), and manually enter the activity that the MSB didn't track. They were asked to record on days 1, 3 and 4, but on the second day they only performed a 24-hr recall of what they ate on the first day. They completed a post-use questionnaire intended to identify useful features, and completed an activity questionnaire. See Snively[ref] for more details.

3.6.1 Final BALANCE Software

Up until this point, the discussion has focused on the design and development of the food diary and visualization components of the BALANCE project, independently. As mentioned earlier, the entire project consists of the feedback visualization, food diary, activity diary, and activity sensing component (MSB) combined together. In this section, describe the activity portion of the system. The activity diary (shown in [ref]) shows both activities entered by the user and activity information detected by the MSB. The user is responsible for entering activity not detected by the MSB, such as swimming or vigorous (?) sports.



(a) (b) (c) (d)

Figure 3.10: Final BALANCE software walkthrough

The activity database is based on the Physical Activity Compendium [ref].

The pager-sized MSB is worn on the user's hip, and is connected to the phone via Bluetooth. The interface supports connecting to and communicating with the device, displaying information about the sensed activities. The software also monitors the connection and notifies the user if the connection breaks.

3.6.2 24-hr recall software.

A 24-hr recall is a process in which a trained researcher works with the participant to identify all the foods that the person ate in the past 24 hrs. Part of the BALANCE validation required identifying how correctly and completely the user entered the food they ate into the mobile phone food diary. To do this, participants were asked to complete a 24-hr recall for the first day of their participation. The protocol is designed to elicit information from the person without "planting false memories", as well as identify commonly forgotten foods.

This process required a tool for the researcher to access the same food database in the same manner that the participants did. We developed a desktop version of the food diary app to support this task.

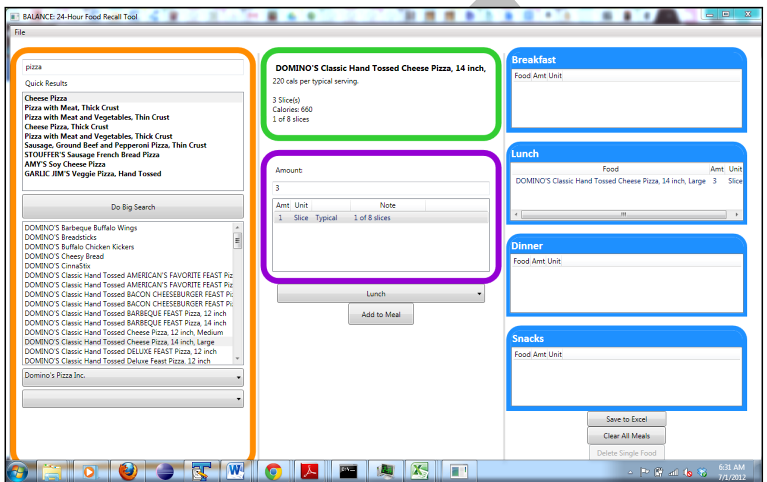


Figure 3.11: WinMobile Food diary

3.6.3 *Metrics*

As mentioned above, our evaluation of the iterative design process was unsatisfactory overall. A secondary goal of this validation phase was to collect more metrics about how the software was used, to try to evaluate or generate some ideas for further research on metrics that may be more informative indicators of the use of the software.

In this section, I describe the metrics we collected, as well as the results. I also address how the reported metric results could help better understand the final validation, which identified a discrepancy between calories entered into the food diary and calories determined via the 24-hr recall. In Chapter [ref], I refer back to this in the larger context of evaluating the use of food diaries. One thing that informs some of these choices is the HCI/Persuasive Tech research community. Technology researchers working in the space of health and wellness have long acknowledged that actual behavior change cannot be the primary measure of success for evaluating tools to help support behavior change. Early prototypes and investigations into the space will need other measures to indicate whether the tool is developing in the right direction or not. In this vein, we are increasingly focusing on “indicators of engagement”, which , loosely defined, are metrics that reflect how engaged an individual is with a particular tool. The reasoning is that the higher the level of engagement (and the more sustained the engagement), the greater the chance for behavior change. That said, no research has clearly shown how useful different indicators of engagement are.

In this section, I report how different metrics change over the five days following the start of the study, per participant. Days 1-4 reflect active participation in the study, while day 5 reflects any modifications to the earlier data. To compare and characterize change in the metrics over time, each study day is broken into 6 4-hr periods, "Early morning" (12-4am) through "Night" (8-12pm). No distinction is made between weekends and weekdays.

3.6.3.1 App Starts Over Time

The first metrics of engagement we consider is how many times the user starts the application. Even if they don't do anything with the app, starting the app usually indicates that the user is thinking about the app. In the case of the BALANCE software, starting the app could reflect a number of things, including that the user just ate and is planning to make an entry, planning to eat and looking up an calorie values, is glancing at the visualization to assess progress in the middle of the day, or is planning to enter a forgotten entry from earlier in the day.

A common descriptive metric to report is the mean number of app starts or entries per day, per participant "participants made an average of 3.26 entries per day"[ref][examples-Wellness Diary]. For BALANCE, that's not informative enough. This project in particular puts value on the user being engaged with the software throughout the day. We want to know if people are thinking about it consistently throughout a day, and how that pattern changes over time. For each participant, we calculated how many times the app was started in every 4-hr time period after their start of the study (midnight of Day 1). Reviewing the data revealed that some people started the app throughout the day, while others only started it once a day, and sometimes people didn't start it at all. Figure 13 shows the counts of participants whose data reflected these behaviors.

If everyone used the software the way we intended them to, the above chart would show 34 people starting the app multiple times throughout the day (blue) on days 1, 3,

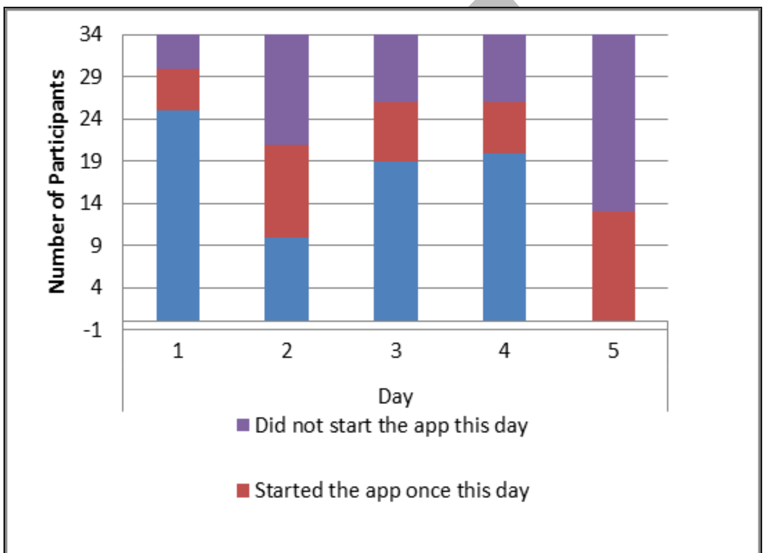


Figure 3.12: App start patterns over the days

and 4 (the days of the study when they are entering their food). However, we see that while many people started the app consistently on the days 1, 3, and 4, it wasn't everyone, and that number decreased on days 3 and 4. From looking closer at the raw data, we saw that 11 people displayed the desired pattern, which indicated that they used the app as requested. 13 people had at least one day (of days 1, 3, or 4) where they didn't start the app at all, and 5 had 2 days when they didn't start the app at all. 2 people consistently started the app 1 time/day for the duration of the study.

One problem with this calculation is that not starting the app doesn't necessarily mean that a participant wasn't *using* the app consistently throughout the study. 2 participants never started the app throughout the study period, but still had valid entries. This can be explained that participants treated the phone as a special device only used to enter their food. Since participants were asked to carry a separate device rather than use their personal phone, they weren't using the device for anything else, and likely had no reason to "quit" and re-start the app.

What does this mean for the validation discrepancy? This data indicate that for the most part, participants were starting the application periodically through the day. This

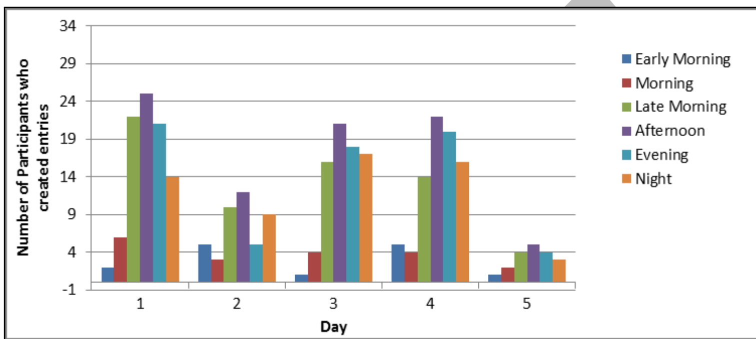


Figure 3.13: Number of people who made entries over time

meant that the discrepancy is probably not due to people forgetting about the application.

3.6.3.2 Entry Creation Time

This set of data is generated by counting the number of entries created in a given time period, over the course of the study. This only counts when a record was created in that time period, and does not account for when a food was entered for a different time. This gives us a better sense for the pattern of entries that are made throughout the study period- WHEN people are thinking about/using the application. It doesn't necessarily correlate with when people actually ate.

Figure 14 shows how many participants created entries during each specified time period. With this population, it was fairly unpopular to make entries in the early morning (between midnight and 4am) and morning (4am-8am), while the late morning, afternoon and evening were the most popular times to make entries.

This chart shows a sum of all the entries entered during a particular time period each day. While the above chart showed the number of participants who made entries in that time period, this indicates how many entries those participants actually made.

What does this mean for the validation discrepancy? Reviewing the charts, we see that day 1 has more people who made more entries earlier in the day, while on days 3 and 4 participants made entries primarily in the second half of the day, and created more

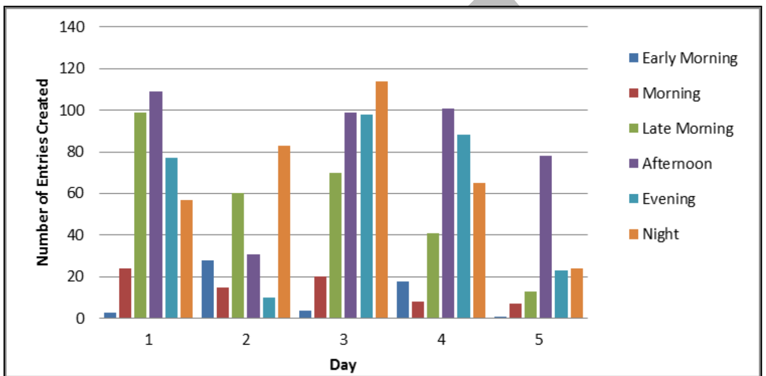


Figure 3.14: Number of entries over time

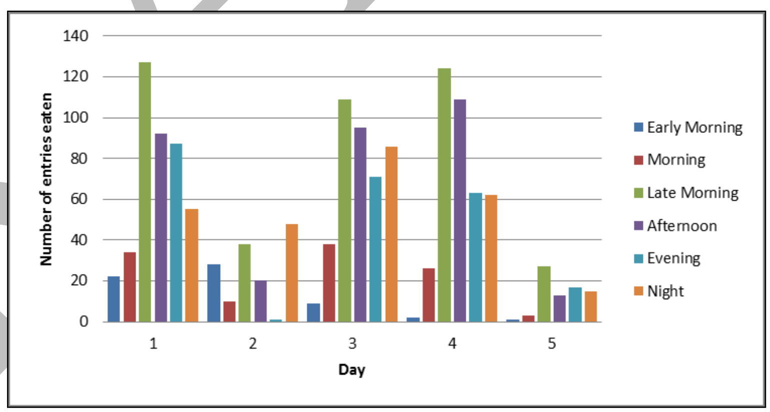


Figure 3.15: Number of entries eaten over time

entries in the second half of the day than in the first half of the day. This indicates that participants were probably entering their food closer to the time that they ate it on day 1, which means the day 1 entries probably more closely reflects what they actually ate.

3.6.3.3 Food Eaten Time

This set of data consists of counting how many valid food diary entries were reported as being eaten in the given time period. The periods of time are again defined in 4-hour chunks, 6 periods per day, so 24 for the study time. For example, on Day 1, Late Morning,

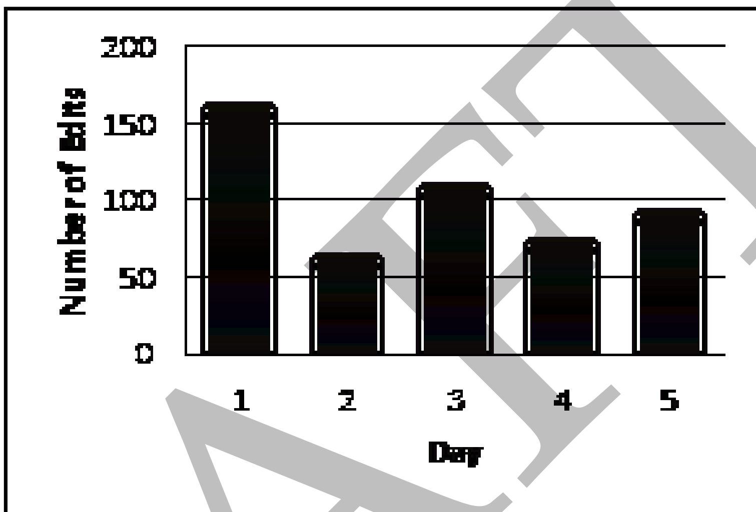


Figure 3.16: Number of edits over time

we see from the previous chart that 100 entries were made, but we see in this chart that while only 100 entries were made in this time period, about 120 foods were reported as eaten in this time period.

A comparison of Figure 15 and Figure 16 indicates that participants likely made entries in the second half of the day capturing food that they ate in the first half of the day.

What does this mean for the validation discrepancy? Similar to the entry creation time, usage on days 3 and 4 indicate patterns that correlate to greater error between what was eaten and what was entered. This appears less extreme on day 1, so again, the entries on day 1 probably more closely match what was actually eaten.

3.6.3.4 Entry Edits

One indicator that users are becoming more familiar and comfortable with a piece of software or an interface is how many errors they make. In this study, the best indication we have for the number of errors people make throughout the whole study is how many edits they make.

The mean number of edits made by participants over the entire study is 13.559, with a

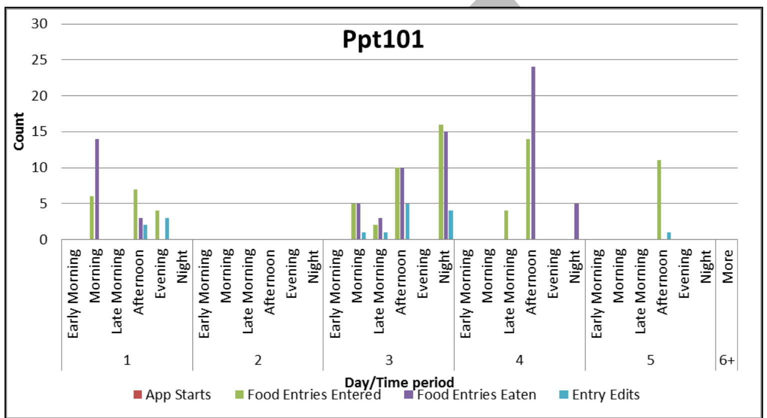


Figure 3.17: Patterns of use, ppt101

standard deviation of 8.33.

Figure 17 shows how many edits were made each day of the study, by all of the participants. The decrease in edits over time could indicate that participants were becoming more comfortable with the software, and making fewer errors in their entries. The increase on day 5 could reflect participants checking their entries to prepare for the completion of the study.

What does this mean for the validation discrepancy? The high number of edits on day 1 could indicate that participants were being conscientious about ensuring that the records were correct.

3.6.3.5 Number Of Combos/Favorites And Their Use

One of the features asked for many times in the focus groups the ability to save and use favorite foods, combinations, and recipes. In the validation study, 2 participants created 2 combos total, and used one of the combinations 2 times in their diary.

3.6.3.6 Combined For One Participant

If this is at all helpful or interesting, I'll improve the chart. If not, I'll take it all out.

To help put it in context, I show the graphs for two different participants.

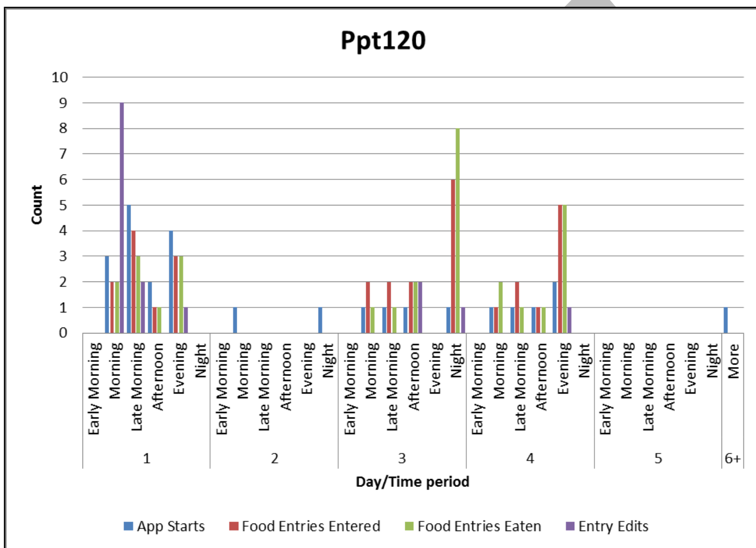


Figure 3.18: Patterns of use, ppt120

I start with Ppt101. As we see in this chart, there are App Starts (red). This is one of the participants who left the software running the entire time, which resulted in not being able to detect when the application was started. In addition to App Starts, this chart shows how many entries were entered in a given time period, as well as how many entries were reported as eaten in the given time period. Summed over all the days, the number of entries entered (green) equals the number of entries eaten (purple). On Day 1, in the morning, more foods were eaten than entered, but in the afternoon more foods were entered than eaten. This shows that the participant entered some of the food eaten in the morning, but later in the day went back and added some more entries. On Day 3, the participant was pretty consistent about entering entries when the food was eaten. On Day 4, many more entries were eaten in the afternoon and evening than were entered, and we can see that on Day 5, there were some more entries made, which explains that the participant went back and filled those entries in.

Ppt120 shows a more consistent interaction with the software. The app is started with each group of entries. For the most part, entries are entered at the time of eating, with a few edits. The first day generally shows more interaction with the software, which is consistent with a period of adjusting to it. Also, while there are many edits the first day, there are fewer edits in later days, which could indicate a greater familiarity with the software.

3.6.4 Discussion

Previous research has identified factors that increase error in food diaries that people create. In the BALANCE validation study, we identified a discrepancy between what they entered and what was reported in a 24-hr recall. Previous work comparing food entries in an electronic food diary to a 24-hr recall found no significant difference [ref], but one difference between that study and this is that the 24-hr recall was performed a few days into a long-term study, rather than on the first day of a 3-day study. This raises the question of whether participants weren't as familiar with the software and device, and that the discrepancy may improve if the comparison was performed on the 3rd or 4th day. However, reviewing patterns of use as indicated by various metrics allowed us to understand that the first day of the study was probably the best data that would be collected in this study.

3.7 Overall Discussion

The BALANCE project provides a rich dataset for us to begin understanding some of the challenges that people encounter when trying to self-monitor their food intake on mobile phones. Over all the studies, almost 50 people used the food diary for 3 days and provided detailed feedback. We were able to collect usage metrics on 34 of those participants, which helped us to better understand some of the patterns of use. All of this data also helped us to better understand how our metrics and methodology impacted the evaluation outcomes. I further elaborate on specific themes below.

Historical Context. One thing that was a major issue for this project was the development and availability of mobile phones throughout the study period. The project began in 2008, and we were using state-of-the-art Nokia N80s. Soon, these were eclipsed by the N95s (with a larger screen and better tech specs). We began running the focus groups in spring 2009, finishing in the fall of 2009. The validation phase began in spring 2010, finishing in the fall (Sept?) of 2010. When we began the project, PDAs had been around for a while, but smartphones were just beginning to merge with PDAs by providing touch screens. Smartphones and appstores were very much a new thing-prior to this period, if someone bought a PDA or a smartphone and wanted to use any software that wasn't already pre-installed on the phone, they needed to be fairly tech savvy, purchase the software and connect the phone to a computer to actually install it. Software usually required a stylus or joystick input, rather than the familiar touch, swipe or gesture interfaces that many are familiar with today. Today's appstores allow new software to be found and installed with just the touch of a finger. Altogether, this means that when we began this project, "lay" people (or maybe, less-technically-savvy) people hadn't really used their phone for much more than a basic phone, although they were increasingly aware of the notion of using "apps" on a phone.

Fast-changing Technology. When we began the focus groups, the phone we gave to participants was considered very cool. One notable comment from a participant was that her teenage son thought she was so lucky to be able to use that phone. However, by the end of the project, comments from participants included things like "the phone is so clunky and slow". Indeed, one challenge we have going forward is that it's not likely to be the same phone model as the existing research that has been done. This is a challenge for researchers, because the process of an evolving interface and technology requires that hardware stay the same, or at least that the underlying technology doesn't change too drastically. However, for a "research program", it's important to be viewed by the participants as at least on par with currently available technology, if not cutting-edge.

Personal Devices. When running studies using mobile phones, it's challenging to determine whether participants should carry a dedicated study-provided device (as well as whether the participant should use their own SIM in that device, or also carry their own personal device) or if the study software should be installed on a participant's personal device. As discussed in [ref Journal of HCI], the latter case may be preferable because the participants are familiar with the device, have all of their contact and other personal data on it, and therefore may be more likely to use the software on a regular basis. However, study prototypes may be unstable and cause the phone to crash, or otherwise interfere with the normal functioning of the phone. In the case of a study-provided device, the participant may be unfamiliar with the device, or have to carry two devices, which may make them less likely to use the software. In the BALANCE studies, we chose to provide study-owned devices to the participants to use in addition to their personal phones because of the technical requirements of the project. This could have impacted participant ability to adopt the software readily.

Consumer Savviness/Experience/Expectations. One challenge of this research project is the difference between using a piece of software or a prototype as a research tool, or if the research is to inform the tool. One challenge of developing mobile applications is that the context matters. The way the software is used in situ can be very different than anticipated in the lab, and therefore an iterative approach is helpful for identifying those unanticipated []. On the other hand, when we are trying to improve on the design of the interface and services, we want feedback on it before building everything out. Therefore, the prototype that is being used to get user input on specific features might not be perfect. Users in the real world are less tolerant of imperfect or unrefined software. Even more, with mobile applications, it's difficult to recreate bugs that users find, and that makes it challenging to identify the true cause of a bug. Users are usually unable to provide enough information about the "bug" they report-as far as they are concerned, it just "doesn't work", or crashes.

Research Prototypes. Given the concerns about consumer expectations of software, and that many mobile-phone food diaries already exist, why build a new one? Existing software is consumer-oriented, and a stand-alone product. This means we can't extend it to work with a novel visualization or the calorie-expenditure hardware, and it also means that we don't have access to the food diary data. Additionally, as discussed above, we are unable to instrument the software to inform us about how it is being used.

Database. The food database had a huge impact on the overall design and implementation of the BALANCE software. There was a tension between needing a database that was big enough to have all the foods that many different people may encounter, but small enough to make it quick and easy to navigate. The information architecture of the database was important too-food groups and categories that are meaningful to experts and professionals may not be obvious to consumers. This is consistent with reports of the importance of high literacy abilities to navigate food and nutrition information [ref].

Study Duration. Choosing the duration of the final validation study required evaluating a tradeoff: reducing the duration put less burden on the participants, but they have less time to become familiar with the software and figure out how to make it fit into their daily schedules. Length of use also impacts the ability of the software to adapt to the participant. The personal database grows based on what people enter, making it easier to find and enter food, and the favorites features also provide a way to minimize interaction time. However, with a duration of three days, the time investment required for personalization will probably not have a large impact on the tracking process. While none of the evaluations showed that the BALANCE software enabled people to keep track of their food intake in a timely, complete and consistent manner throughout a day, this is consistent with other work that indicated technical malfunction prevented statistically significant results [ref]. Participants reported that the idea of tracking their food intake on their mobile phone was appealing, and offered valuable insight as to how we as designers and researchers may improve the process, particularly by reducing the amount of effort that goes in to the food intake capture. This allows us to raise the question of whether people will be able to enter food intake on a consistent basis if we reduce the amount of effort, in terms of time, physical entry (entering text or pushing buttons) and mental activity (how much the user needs to think about the process). This is addressed in the next chapter.

3.8 Summary

In this chapter, I describe the BALANCE project, focusing primarily on the design and development of the food diary component of the project. I also provide an HCI-oriented evaluation of the use of the BALANCE software by participants in-situ, to better understand the results of the more quantitative, [medical]-oriented evaluation. This HCI-oriented evaluation identified that one important barrier to participants creating complete, comprehensive and timely food entries is due to the database. I document the challenges of using a food database on resource-constrained devices such as mobile phones, and [prove that nothing more could be done to improve the database experience with this technology]. The database is challenging to navigate and requires mental effort, particularly in real-world context, in addition to requiring time-consuming text entry. User feedback indicated that people understand the value that dietary self-monitoring could provide, but that the BALANCE food diary required too much time. It also indicated that people might be willing to accept a less detailed accounting of their food intake in exchange for a less challenging/time-intensive collection process.

Chapter 4

CONTRIBUTION 2: INVESTIGATING FOOD INDEX-BASED FOOD DIARIES IN THE LAB

In this chapter, I address the question of what challenges arise when tracking food intake as an index on a mobile phone. In earlier chapters, I described the challenges and barriers that people face when employing a traditional approach to journaling what they eat, either on paper, a website/software, or on a PDA/mobile phone. Here, I make the argument for the value of a different paradigm of food journaling. Specifically, I refer to the constraints that a mobile platform imposes on the food journaling problem as discussed earlier, and consider how the use of food indexes could address the given constraints. I also describe how the use of food indexes for mobile phone food journaling naturally reflects known requirements for successful goal-tending. After establishing the potential benefits of the approach, I will address some questions that arise around the approach of using food indexes for mobile phone food journals. I then describe a study where I explore some of those issues and present the results.

4.1 Introduction

The BALANCE project highlighted the challenges of tracking dietary intake on a mobile device. Since many of the challenges were either directly or indirectly related to the database, we decided to consider the problem of tracking dietary intake without the database, believing this could help to streamline the food intake capture process. Tinker et al [ref] discuss the potential benefits and drawbacks of "brief survey" tools, pointing out only three examples [ref][ref][ref] of previous work that compare the outcomes of brief survey versus full survey food intake tracking tools. We have identified more work that has described some brief survey tools [ref], but none have been compared to more traditional food intake tracking tools.

To inform the design of a new brief survey tool, we first considered the larger goal of the BALANCE project, which was to help people self-monitor their energy intake and expenditure to help either attain or maintain a certain weight. Self-monitoring is a tool to help support behavior change, in this case, around health and wellness behaviors. Self-monitoring not only helps people become aware of their current behavior, but identify if it is changing or not. This is related to goal setting and tending-once awareness is developed via self-monitoring, one can begin to start targets for change. This raises the question of what kind of behavior change we can support with no food database. A tool can't easily support calorie counting without a database for lookup. However, researchers are interested in other health and wellness indicators such as the quality of an individual diet.

Diet quality is a factor in preventing and treating many diseases, such as cancer [ref], cardiovascular disease [ref], and diabetes [ref]. Research has also shown that a diet high in nutrient dense food tends to be lower in calories [ref]. Tools to support people in improving their diet quality, especially by increasing the amount of nutrient dense foods they consume, can help them to decrease the number of calories they consume.

Diet quality is usually measured as a reflection of the pattern of food that an individual consumes [ref], as opposed to values of specific nutrients [ref][Kant][Kourlaba]. Different patterns reflect different values of food pattern quality. For example, two dietary patterns commonly referred to include the Standard American Diet (SAD), which reflects how many Americans eat, and the Mediterranean dietary pattern (MedDiet), which reflects traditional eating practices in the Mediterranean. Diet quality is measured and evaluated is through the use of a food index. Food indexes usually consist of a number of components that are scored and then combined together to one overall score. Improving any of the component scores improves the overall score. Food indexes are thoroughly evaluated to ensure that they accurately represent a given diet. Further research investigates the correlation between a given food index and incidence of disease.

Traditionally, food indexes have been used by experts to evaluate the diet quality of an overall population. Researchers take a form of diet records (e.g. 24-hr recall, food frequency questionnaire), then calculate the components and overall score according to a set of rules. The report of the food index scores can be used to compare different populations (for example, men versus women in a particular geographic area), compare the change in diet quality over time, or identify areas where certain populations can improve their dietary intake. In the absence of a database, food indexes could be a good tool for individuals to track their dietary intake. However, food indexes were developed to be used by experts, and it's unclear what difficulties individuals will have in using them to characterize real food.

In this chapter, I address the questions of how individuals can use food indexes to directly track their dietary pattern and quality, if there is a benefit in terms of reduced time to make an entry, how correct entries are, and if there is any perceived benefit to the users.

4.2 Food Indexes: Analyzing Diet Quality

Dietary or food indexes attempt to describe the quality of the diet that a person or population consumes. An index has multiple components, which are weighted and scored differently, then combined to result in one overall number that describes an individual's diet. Research in the nutrition, epidemiological and medical fields correlate the value of different indexes to health outcomes, such as reduced incidence of cardiovascular disease, cancer, or simply mortality [ref]. This makes them appropriate for consideration as a tool to support disease prevention.

Traditionally, food indexes are used to understand the diet quality of a population as opposed to an individual. An index definition is usually comprised of multiple components and target consumption amounts. Components are either to be moderated (ie, to place an improved score on consuming less) or attained (i.e., to eat at least a certain amount). Components are based on food groups (fruits, vegetables, grains) or nutrients (sodium, fat, protein) [ref]. There are three basic groups of indexes, based on how they are created: those based on recommended dietary intake of micro- and macro-nutrients (calories, fat, protein, Vitamin A, sodium, fiber), an idealized/preferred dietary pattern (such as the Mediterranean diet), and food groups. An index based on recommended dietary intake uses nutrition databases to determine the macro-and micro-nutrients in each food eaten, and then generates a score via a formula. Indexes or scores based on an idealized pattern focuses more on the kinds of decisions people make about what they eat: choosing lean meats over fatty meats, and olive oil in place of butter. Finally, indexes based on food groups count how many servings of each food group is consumed. Overall, food indexes are discriminate between a diet full of nutrient dense foods and diets high in calorie-dense, nutrient-poor foods.

An index is used by taking a traditional food journal that consists of a specific food eaten. For discussion purposes, I will refer to a cheeseburger as the specific food. The researcher will code the food in terms of the food index components. With a food group-based index, the cheeseburger might be coded as "2 servings of grains (the bun), 1 serving of protein/meat (the patty), 1 dairy serving (the cheese)". Once the coding is done, an overall score is generated based on a formula accounting for how each component should fit into the larger diet. Scores are sometimes averaged together over populations, which allows researchers to more easily compare or summarize food intake of a large number of people.

For the purposes of this study, we have identified food indexes that are representative of the different types of food indexes. They are the Healthy Eating Index-2005 (HEI) [ref] and the Food Based Quality Index (FBQI) [ref]. The HEI is based on food groups and nutrient amounts, while the FBQI is based only on food groups. We felt it important to choose two indexes that embodied these characteristics for the purposes of exploring how these types of indexes appeal to users. We are choosing to not use an index based on the Mediterranean diet. An index based on an idealized dietary pattern assumes that the user has previously committed to a particular diet philosophy.

4.2.1 The Healthy Eating Index-2005

The HEI food index [ref] is summarized in the table below. HEI is a score based system, with a perfect diet obtaining a score of 100 points. Each of 12 categories contribute to the overall score. The categories marked in orange are attainment components, and are added to the overall score (to get a high score, a person needs to eat in these categories), while the categories marked in green are to be moderated, thereby reducing the score (consuming more than the specified amount in those categories reduces the overall score). Additionally, the value that counts for a point is dependent on the recommended number of calories a person should intake in a day.

Table 4.1: HEI Calculation

Component	**Maximum Points**	**Daily Recommended Intake**
Total Grains	5	≥ 3.0 oz eq/1000kcal
Whole Grains	5	≥ 1.5 oz eq/1000kcal
Vegetables	5	≥ 1.1 cup eq/1000kcal
Dark green & orange vegetables, legumes	5	≥ 0.4 cup eq/1000kcal
Total Fruits	5	≥ 0.8 cup eq/1000kcal
Whole Fruits	5	≥ 0.4 cup eq/1000kcal
Milk	10	≥ 1.3 cup eq/1000kcal
Meat and Beans	10	≥ 2.5 oz eq/1000kcal
Oils	10	≥12 g eq/1000kcal
Saturated Fat	10	≤ 7%of energy
Sodium	10	≤0.7 g/1000kcal
Calories from Solid Fats, Alcoholic Beverages, and Added Sugars	20	≤ 20% of energy
Total Points	100	

Grains, vegetables and fruits are broken into multiple categories. The grains category is separated into Whole and Total grains, as is the Fruit category. For Grains, once the daily limit is met for Whole Grains, more Whole Grains are counted under Total Grains. If a person eats 5 Whole Grains and 5 Total Grains, the grains component of the total score is 10. However, if a person eats 10 Total Grains, the grains component of the total score is 5, since none were Whole Grains and the max Total Grains score is 5. This is similar with

Fruit, where Whole Fruits include unprocessed fruits, while Total Fruits includes juices and cooked or dried fruits. Vegetables also include two categories, separating out the dark green and orange vegetables, as well as legumes. Similar to Grains and Fruits, if one eats the equivalent of 10 points of Dark Green Vegetables, the total score is 10, while 10 points of other vegetables only contributes 5 points to the total score.

The rules to calculate an HEI score for an individual diet are fairly complicated. However, partly due to the complexity, researchers find the resulting score a fairly good indicator of one's diet [ref]. The complexity makes it a good option for this study, to identify user responses to a complex interface and counting process. It also incorporates the restricting some important quantities.

4.2.2 The Food-Based Quality Index

The Food-Based Quality Index (FBQI) [ref] is a food index based solely on food groups. The food groups are simplified and slightly different than the ones based on the Food Pyramid. Specifically, potatoes, rice, pasta, and other starchy grains are considered separately from either bread (and cereal grains) or vegetables, while cheese is separate from dairy. Serving specifications are designed to be representative of how consumers think about food servings.

Table 4.2: FBQI Calculation

Component	**Points**	**Serving goal**
Bread (incl. breakfast cereals)	1	5-7 slices
Potatoes (incl. rice, pasta & pulses)	1	3-5 pieces
Vegetables	1	3-4 serving spoons
Fruit	1	2 pieces
Milk & milk products	1	2-3 glasses
Cheese	1	1-2 slices
Meat, fish & eggs	1	115-130 g

4.3 Food Tasks: Food Diary Evaluation Methodology

One area of focus was the food tasks. Since we want to apply the findings of this study to the real world, one approach is to use a food diary or recall of that participant. This gives the benefit of a person being familiar with the food, and it would allow us as researchers to identify how the interfaces do or do not support the real world food. Familiarity is important, particularly with the index-based approach, because if people don't know what is in a food they are more likely to get it wrong. However, people have different foods they are familiar with, particularly in terms of content. Familiarity can depend on age, religion, geography, vegetarian or not, even gender. However, if each participant used different foods, we wouldn't be able to compare timing and correctness measures for the different interfaces. Also, some participants might eat more "single component" foods while other participants eat more combination or restaurant foods, which are more challenging to score. Therefore, we decided it was best for all participants to use the same food tasks.

Because the issue of familiarity is so important, we carefully considered how to choose the food for the tasks. One considered approach was to refer to a published gold standard. [blah blah, not published, not an issue in nutrition research, etc.] We considered using published diet plans, such as those advocated by the American Heart Association for healthy diets. The drawback to those is that they are recommended, and may not accurately reflect the actual diet of the participants. Additionally, since the recommended menus are based on the official Food Pyramid, and one chosen food index is also based on the Food Pyramid, this could influence the correctness scores. After consideration, we decided to choose the food tasks based on the food diaries collected in the BALANCE focus groups. Since the study populations are drawn from the same underlying populations, the issue of familiarity is addressed. More details are explained later.

Another important aspect is how the food tasks are presented to participants. In the real world, one of the important challenges to "perfect" food journaling is the process of seeing/eating food, identifying what it is, sometimes identifying methods of preparation (fried versus broiled), identifying un-seen characteristics (low-fat versus full-fat milk, with butter), and identifying portion or serving sizes in order to correctly enter the food (or choose from a list in a db). Sometimes this process is easy, as with packaged foods or when preparing your own food; other times such as at a restaurant it's more challenging. Literacy is also an issue: with a traditional journaling approach, it's one thing to be able to identify one cup of spaghetti, but if you aren't able to spell it properly, you might not be able to find it in a database. Due to this process, we considered that using real plates of food would be more life-like, and that using photographs of food were close to real. However, with the use of photographs, care must be taken to obtain them properly. Scale and lighting are two important considerations. And, with research, we found that there exist food photograph booklets specially prepared for the purpose of studying people's estimation of portion sizes. However, these booklets had the familiarity concerns outlined above. We decided that portion size estimation and literacy were not primary concerns for this study, so chose to present food tasks as a list of foods on a card.

4.4 Comparing Food Index-Based Mobile Phone Food Diaries

In this section, I talk about the evaluation I did to explore this area of tracking diet quality or food-index based tracking.

4.4.1 Research Aims

1. Is it faster to enter food in a complete, index-based mobile phone food diary?
2. Are people able to enter food correctly in a complete, index-based mobile phone food diary?
3. Are the work-load satisfaction measures the same for index-based mobile phone food diary as a traditional food diary?
4. How can we characterize the types of errors that are made in an index-based mobile phone food diary?

In addition to the above research questions, we designed this study to support generating design recommendations for future index-based food diaries.

4.4.2 *Study Design*

We performed a comparative evaluation of the BALANCE interface with two food index-based food diaries. The other food diaries were based on HEI and FBQI. All interfaces were ran on a Windows Professional Mobile smartphone with a slide-out, qwerty keyboard.

4.4.3 *Instruments*

This study focused primarily on understanding the interaction between people and a food index via a mobile device.

Since this study was to focus primarily on interaction concepts and features, the HEI and FBQI were designed from this perspective. The BALANCE interface was a stripped-down version of the software designed for the BALANCE study, described in the previous section. In particular, it was important for the interfaces to be simple and similar where possible. The HEI and FBQI were designed to show all of the food groups on the start/welcome/home screen, with progress towards that day showing as checks in each group. Each group had an example button accessible from this screen, to help users answer the question "I just ate a food; which group does it go in?". For this pilot, the examples were taken from literature describing the indexes. One click/touch on a food group button displays a serving size screen, with examples of foods in that group and sample serving sizes. The widget for specifying servings were specifically discrete buttons that could be toggled on and off. They act more like a slider however, as when (for example) a multiple-sized entry is made, all the others are selected. (Clicking the 3 oz button selects the 1, 2, and 3 oz buttons). Time was spent trying to determine a more attractive interface, for example by using images to depict the foods that go in a group. However, we decided that was not the important part of this study, and so opted to simplify the interface instead. Colors were chosen to be similar for similar groups in HEI and FBQI, but since the groups were slightly different they were matched as best as possible. The overview needed to fit onto one screen, for both an easy way to view the overview as well as easy to make a new entry.

Guiding Design Principles:

- One screen

- Overview shows progress but not goals
- Individual screens inherently showed goals
- One handed use

4.4.3.1 HEI

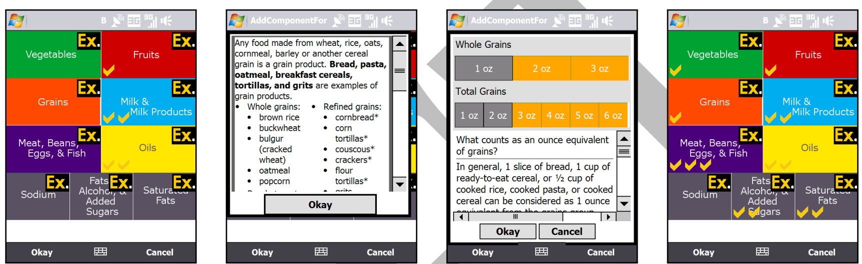
It is straightforward to convert the HEI index into a points-based system that is appropriate for our indexed-based system. For the study, we assumed a daily recommended intake of 2000 kcals. The official recommended intake for healthy adults is roughly 1900-2400 kcals/day. In real-world usage, the interface can reflect an individual's need, but for the study this was fine. We then calculated the recommended intakes for each group. For the interface, we made small adjustments to the amounts to target intakes to make it easier to count "points". We then chose a number of boxes to use to represent the points that was fairly straightforward and more human-friendly. For example, we rounded 2.2 cups of vegetables up to 2.5 cups, and presented it as 5 boxes, so that each box represented 0.5 cups of vegetables. This appears friendlier than 5 boxes with each representing 0.44 cups. We edited the "What's in a serving" text to reflect the amounts that each box represented. For the Vegetables, Fruits and Grains categories, where there are two sub-categories of foods, we ensured that each box for both sub-categories represented the same amount. For example, in the case of Grains, the target for Whole Grains is 3 oz, while the target for Total Grains is 6 oz. Rather than have 6 boxes for each (which means that the boxes for Whole Grains would represent 0.5 oz while the boxes for Total Grains would represent 1.0oz), we chose to have 3 boxes for Whole Grains and 6 boxes for Total Grains, and each box represents 1 oz.

For the purposes of this study, we collapsed Fruit, Vegetables and Grains into single categories, each with two sub-categories. We did this to reduce the complexity of the overview screen for two reasons. First was because we wanted the overview screen to contain all of the index components and still be simple, uncluttered, and one-hand usable. Putting three more boxes on the overview screen would make the boxes too small. When the boxes are too small, they're more difficult to target/touch, and also have less space to show the checkmarks that identify current progress/status for the day. The second reason was that we wanted to reduce the cognitive load at the overview level. There are two tasks that we want to support with the overview screen: answering the questions of "how is my progress so far today?" and "Where do I put this food?". To answer the "Where do I put this food?" question, the fewer number of answers that are possible makes it an easier question to answer. For that immediate moment, it's easier (and quicker) for a person to judge "is this carrot a fruit or a vegetable?"; once they get to the servings dialog, they can address the "is it orange or not?" question.

Table 4.3: Counting HEI as 'tokens'

Component	Goal		Num Boxes	Daily Recommended Intake
Total Grains	6 oz	6 oz	6	$\geq 3.0 ozeq/1000kcal$
Whole Grains	3 oz	3 oz	3	$\geq 1.5 ozeq/1000kcal$
Vegetables	2.2 cups	2.5 cups	5	$\geq 1.1 cupeq/1000kcal$
Dark green & orange vegetables, legumes	0.8 cups	1 cup	2	$\geq 0.4 cupeq/1000kcal$
Total Fruits	1.6 cups	1.5 cups		$\geq 0.8 cupeq/1000kcal$
Whole Fruits	0.8 cups	1 cup		$\geq 0.4 cupeq/1000kcal$
Milk	2.6 cups			$\geq 1.3 cupeq/1000kcal$
Meat and Beans	5 oz	5 oz	5	$\geq 2.5 ozeq/1000kcal$
Oils	24 g	25 g	5	$\geq 12 geq/1000kcal$
Saturated Fat		7.5g	5	$\leq 7\% of energy$
Sodium	1.4 g			$\leq 0.7 g/1000kcal$
Calories from Solid Fats, Alcoholic Beverages, and Added Sugars				$\leq 20\% of energy$

The main screen of this application shows an overview of the index. Each colored



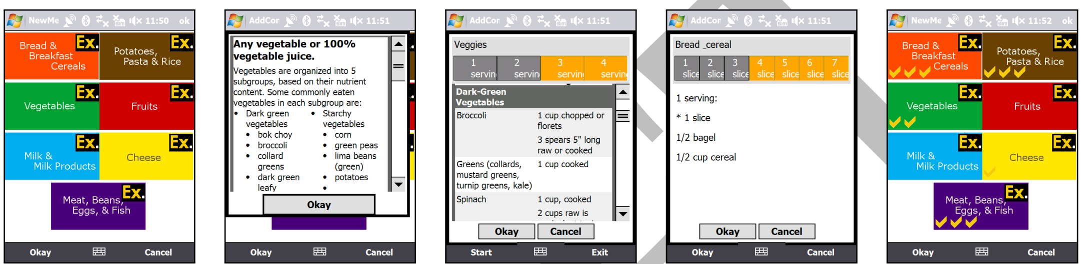
(a) Viz1 (b) Viz2 (c) Viz3 (d) Viz4

Figure 4.1: HEI Screens.

button represents a component of the index, labeled as such. An “Ex” button on each component button provides support for the user to determine which group/component a particular food belongs to. The “Ex” button for Grains is shown above. With HEI, many of the components(Vegetables, Fruits and Grains) are broken down into sub-components. Once a component button is selected, a window pops up which allows a user to specify how many servings they want to enter. Again, the example/explanatory information is presented on this page, to support the user in determining how many servings to select. For this study, the serving sizes was based on the formal HEI specification. We see in the case of grains, this is ounces of grains. The examples and explanatory guidance text is adapted from information provided by official food pyramid guidance. After the servings are selected, the overview screen shows checkmarks to represent the number of servings eaten in that category, accumulated for the day.

4.4.3.2 FBQI

The FBQI interface is similar in design to the HEI inteface. This is specifically to attempt to minimize differences between the interfaces. As in HEI, the main screen shows an overview of the index. Each colored button represents a component of the index, labeled as such. An “Ex” button on each component button provides support for the user to determine which group/component a particular food belongs to. The “Ex” button for Grains



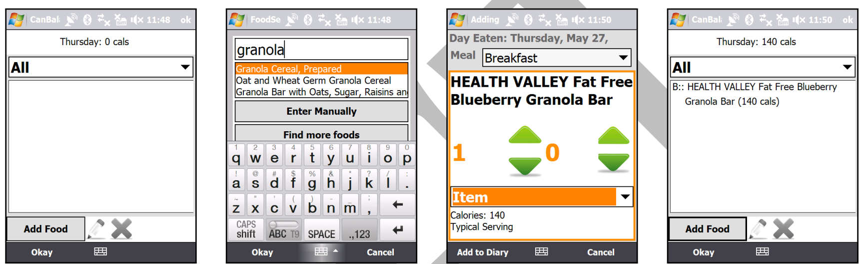
(a) Viz1 (b) Viz2 (c) Viz3 (d) Viz4 (e) Viz4

Figure 4.2: FBQI Screens.

is shown above. Once a component button is selected, a window pops up which allows a user to specify how many servings they want to enter. Again, the example/explanatory information is presented on this page, to support the user in determining how many servings to select. The serving sizes and guidance are based on the official definition of the food index. We see that for FBQI, the guidance is much more streamlined, which is indicative of the point that the index is designed for experts, as opposed to novices. The simplification in some ways is nice for lay-people, but in reality it frequently doesn't provide enough guidance for the various foods people encounter in their diet. The examples and explanatory guidance text is very similar to the guidance provided for HEI, and adapted from USDA food pyramid [ref] guidance. After the servings are selected, the overview screen shows checkmarks to represent the number of servings eaten in that category, accumulated for the day.

4.4.3.3 BALANCE

The main, overview screen for the BALANCE software consists of a list of food eaten that day. For each food item, the name, number of calories, and meal is identified. The number of calories for that day is specified at the top of the screen. New entries are added by searching for a key word or name. After 3 letters are entered, a list is displayed that shows food entries (from a list of foods that contain common foods and foods that have been en-



(a) Viz1 (b) Viz2 (c) Viz3 (d) Viz4

Figure 4.3: BALANCE Screens.

tered by that user before) that contain words starting the same way. After a specific food is chosen, a screen appears where the user can specify the amount eaten, in full and partial servings. Some foods provide multiple serving choices, such as ounces, cups, grams, pieces, or servings. This information is provided by the nutrition database, and is limited to the serving information in this database.

4.4.4 *Participants*

12 participants, recruited from online campus newspaper. The mean age was 31.6 years, median age 28.5 years; 8 females. 7 participants owned a phone with a touch screen, 5 owned "feature phones". Of the 12 subjects, 10 of them reported using their cell phone either daily (1-2 times per day) or several times a day, while 2 reported using their phones approximately 1-2 times per month. 7 reported entering text (such as text messages or adding/modifying contacts) on their phones either daily (1-2 times per day) or several times a day, while 3 enter text approximately 1-2 times per week and 2 almost never enter text on their phones. Of participants who enter text on their phones, 5 use a 12-key keypad; 3 use a touch screen or soft keyboard; and 3 use a QWERTY or hardware keyboard.

4.4.5 Procedure

Participants came to the lab, and began by filling out a questionnaire that included basic demographic data, questions concerning the participants' daily cell phone use, current health and wellness goals, and experience journaling food intake.

Then, for each interface, they were introduced to the interface and given two practice tasks to perform. The practice tasks were the same for all interfaces. One practice task consisted of only single foods, and the other practice task consisted of combination foods. After the practice tasks, the participants were given a chance to ask any questions or take a break. They were then notified that the real tasks were starting, and asked to work as quickly as comfortable between the start of a task and the end.

A task consisted of a meal, which was printed on a card. At the start of each task, the task card was set on the table next to the participant, and phone displayed a screen that identified the coming task (by task ID). This allowed the study administrator to ensure that the correct task was being timed (by comparing the task ID on the screen with the card). When the participant is ready, they click on the "Start Task" button, then refer to the task card for entries. When the participant believes the task is complete, they click the "done" button. Another screen showed that the task was over. The participant then clicks "next task" when they are ready, and the cycle starts again. One day of meals was completed in each condition. This consisted of a breakfast, lunch, dinner, small snack, and large snack. After each condition, participants filled out a TLX survey and asked what they like best and least about each condition. The presentation of food days and order of conditions was counterbalanced.

After all three conditions were complete, the participants were asked to complete a final survey on the computer.

4.4.6 Tasks

For each condition, participants will have "food tasks" for the participants to enter. Food tasks are broken down into "meals", and there will be a controlled set of foods in each meal.

There were 3 days of food tasks. Each day consisted of a breakfast (3 food items), small snack (1 item), lunch (4 items), big snack (2 items), and dinner (6 items). Each day was chosen to control for number of items, number of calories, and number of index components. Foods and meals were chosen from a previous study that collected food journals from a similar population. This ensured that most foods would be recognized and familiar. Specifically, foods were chosen only if they existed in the nutrition diary that BALANCE is based on. This has the benefit that we can more closely compare things like time to enter between conditions, but it is clearly not representative of the real world, where many foods are not included in the database. This is a problem that has proven to be a barrier for many food diaries.

4.4.7 Study Design Limitations

This study simplifies the food journaling process in order to directly compare the strengths and weaknesses of the specified interfaces. There are three primary limitations to the design of this study. Specifically, it does not address the problem of either estimating or measuring serving sizes, since serving sizes are specified and written down. Also, none of the tasks include foods that are not in the database, which is a known problem in the real world. Finally, the design does not account for journaling food intake within the real-world context that food journaling frequently requires.

4.4.8 Data Collected

The data collected is described in more detail below. Special attention is given to the treatment of how to count task responses as correct.

Errors. Difference between the ideal or expected task response and what the user entered. An error was identified as a difference between a participant's food entry (the final "daily" entry") and the expected/perfect entry.

Timing/Duration. Time spent in each condition. Time was calculated as the sum of time spent in each meal, starting when the "start" button was clicked and stopping when the "done" button was clicked at the end. Time between meal tasks was not counted.

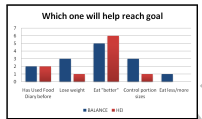


Figure 4.4: Answers to “Which will help you reach your goals?”

TLX. Self-reported measure of workload assessment. After each condition, participants filled out a NASA-TLX survey [ref]. Items include Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration, and are rated on a 7-point Likert scale.

Rankings. Ordering of the interfaces on four features. At the end of the study, participants ranked each interface in terms of preference, ease of use, understandibility, and usefulness.

Useful for goals. Self-reported indication of how useful each interface would be to help reach goals. At the end of the study, participants were asked which single interface/condition they felt would be most helpful for them to reach their health/wellness goals, and why.

Length of use. Self-reported duration a participant would be willing to use the interface for. At the end of the study, participants were asked which interfaces they felt they could use for 3 days, 3 weeks, and 3 months.

Likes/dislikes. Self-reported features that participants liked or didn’t like. After each condition, participants were asked to list 3 things they liked about the previous condition, and 3 things they didn’t like.

Correctness. A value indicating how correct the task response was. A task is assigned 2 points for entirely correct, 1 point for mostly correct, and 0 points for not correct. A participant can get a maximum score of 10 in each condition. Entirely correct means it is exactly ground truth; mostly correct means that there was a small difference that was not entirely correct, but the meaning was close (for example, replacing “feta” with “blue cheese”, or “Hidden Valley Ranch Dressing” with “creamy salad dressing” in the BALANCE condition). This was done by inspection by the lead researcher.

This approach to measuring correctness is due to the complexity of comparing errors across conditions. In all three conditions, it was common for users to provide an answer that was close to correct, but not entirely. This approach, in conjunction with a more thorough analysis of the exact errors that were made, allows us to better compare how well participants performed in each interface.

4.4.9 Hypotheses

Hypotheses we're testing: 1. Both of the index-based interfaces (HEI and FBQI) will be faster than the BALANCE interface. 2. The FBQI interface will have more errors than the BALANCE interface; HEI interface will have more errors than the FBQI interface. 3. The TLX workload measures will be the same for all three interfaces. Can we begin to characterize the types of errors that are made in a complete, index-based mobile phone food diary?

4.4.10 Data Analysis and Results

4.4.10.1 Analysis Approach

I think I want a paragraph here: Something about how we do some quantitative tests, then provide some qualitative analysis to help better understand the quantitative results and guide future research. The qualitative analysis includes discussion about the answers to the like/dislike survey question (for each interface), the types/kinds of errors made in each condition, and a discussion of the question "which interface will help you reach your health and wellness goals?".

4.4.10.2 Results

4.4.10.2.1 Correctness We use this measure to test Hypothesis 2, that the FBQI interface will have more errors than the BALANCE interface, and the HEI interface will have more errors than the FBQI interface.

We have 1 categorical independent variable (interface) and 1 continuous dependent variable assumed to be normal. In the univariate repeated measures ANOVA, Mauchly's

Table 4.4: Summary of statistical analyses

Measure	Test	Significance	Values to report
Correctness	1-way repeated measures ANOVA	Y	(F2,22=17.074, p¡0.0001).
	Paired t-test	Y	
Duration	1-way repeated measures ANOVA	Y	(Wilks Lambda = 0.154, F2,10=27.49, p¡0.0001).
	Paired t-test	Y	
TLX:			
Mental Demand	Friedman test	Y	(χ^2=10.56, N=12, df=2, p¡0.01).
	Wilcoxon	N	With Bonferroni correction, no pairwise comparisons are significant.
Discouraged	Friedman	N	(χ^2=2.595, N=12, df=2, p=0.273).
Ease of use		N	(χ^2=3.556, N=12, df=2, p=0.169).
Quickly	Friedman test	N	(χ^2=1.333, N=12, df=2, p=0.513).
Learn	Friedman test	N	(χ^2=0.963, N=12, df=2, p¡0.618).
Successful	Friedman test	Y	(χ^2=16.89, N=12, df=2, p¡0.0001).
		Y	HEI vs BAL: (z=-2.831, p¡0.01)
	Wilcoxon	Y	FBQI vs BAL: (z=-2.825, p¡0.01)
		N	FBQI vs HEI: not significant
Rankings			
Preference	χ^2 test of proportions	N	(χ^2=4.5, N=12, df=2, p=0.105).
Understandibility	χ^2 test of proportions	Y	(χ^2=9.5, N=12, df=2, p¡0.01).
	χ^2 test of proportions: BAL vs FBQI	Y	(χ^2=6.4, N=10, df=1, p¡0.05).
	χ^2 test of proportions:	Y	(χ^2=4.46, N=11, df=1, p¡0.05).

sphericity test is not significant (?2=1.351, N=12, df=2, p=0.509). The results, assuming sphericity, indicates that timing is significantly different with each interface (F2,22=17.074, p¡0.0001).

Pairwise comparisons using Holm's sequential Bonferroni procedure show that HEI is significantly less correct than FBQI (p¡0.017) and BAL (p¡0.025), but that FBQI is not significantly less correct than BAL.

4.4.10.2.2 Timing/Duration Here we address Hypothesis 1, that HEI and FBQI interfaces are faster than the BAL interface.

A single, categorical independent variable and a single, continuous, normally-distributed dependent variable. Since Mauchly's test is significant, we can use either the multivariate test or the univariate test with correction. A multivariate repeated measures ANOVA indicates that timing is significantly different with each interface (Wilks' Lambda = 0.154, F2,10=27.49, p¡0.0001). In the univariate repeated measures ANOVA, Mauchly's sphericity test is significant (?2=8.127, N=12, df=2, p¡0.05). Therefore, we report Greenhouse-Geisser corrected test, which indicates that timing is significantly different with each interface (F1.23,14.14=21.115, p¡0.0001). All pairwise comparisons are significant using Holm's sequential Bonferroni procedure (alpha = 0.05). We can accept our alternative hypothesis that HEI and FBQI are faster than BAL, and more so, we have found that FBQI is significantly faster than HEI.

4.4.10.2.3 TLX Here, we test our third hypothesis about the TLX workload measures. For each question, a single, categorical, multi-level independent variable and a single, continuous dependent variable.

For each of the 7 TLX ratings, we use the Friedman test to determine if there is a significant difference between each of the 3 interfaces. If the Friedman test has a significant result, we use Wilcoxon test on a pair-wise basis to identify which pairs are significant.

Only 2 TLX measures resulted in a significant Friedman test, Successful (?2=16.89, N=12, df=2, p¡0.0001) and Mental Activity (?2=10.56, N=12, df=2, p¡0.01). Follow up Wilcoxon tests (with Bonferroni correction) show that there are no significant pair-wise differences in Mental Activity (although it was very close), but with Successful, HEI is significantly lower than BAL (z=-2.831, p¡0.01), and FBQI is significantly lower than BAL (z=-2.825, p¡0.01), but there is not a significant difference between FBQI and HEI.

4.4.10.2.4 Rankings Performed a 1-Sample ?2 test of proportions based on the #1 rankings for each item, to determine if the distribution of #1 rankings were significantly different than chance for each ranking item. The expected proportions are that each interface is ranked #1 the 33Of the four rankings (preference, ease of use, understandability, and usefulness), only Understandability is significantly different than expected. Follow-up pair-wise ?2 testing revealed that significantly more people found BAL more understandable than FBQI (?2=6.4, N=10, df=1, p¡0.05), BAL more understandable than HEI (?2=4.46, N=11, df=1, p¡0.05), but not a significant difference between FBQI and HEI.

While the ?2 test for usefulness did not have a significant result, it poses an interesting case as no one ranked FBQI as #1 in usefulness.

4.4.10.2.5 Useful For Goals At the end of the study, participants were asked which interface they thought would help them reach their health and wellness goals. Participants only chose BAL or HEI as an answer to this question, hence FBQI is not shown below. The chart below presents the answers to this question, combined with responses to the question (asked at the beginning of the study) “What are some of your health and fitness goals?”. This was a multiple choice question with a write-in option.

Finally, we asked participants which one they thought would be most helpful in reaching their nutrition goals. The above chart shows the choice that participants made, separated out into the goals they reported at the start of the study. Participants selected BALANCE for the goals that depend more on quantitative data (losing weight which requires counting calories, controlling portion sizes, and eating less or more), which provides more detail. Participants selected HEI for goals that are more qualitative (eat “better”). This led us to the question of whether one approach or the other reflects whether an individual’s nutrition goal is quantitative or qualitative.

4.4.10.2.6 Error Analysis In this section, I breakdown the errors participants made in BALANCE and FBQI. The process we used was to identify all items with errors, and then characterize them.

4.10.2.6.a Most Challenging Tasks

Here, we discuss the tasks that were most challenging for participants in the different conditions. No task in the BALANCE condition was entirely wrong (all scores are above 6), and as our correctness score above reports, the most error-ridden condition was HEI. Using HEI, there were two tasks that no participant entered correctly a dinner consisting of (Spaghetti, peas, parmesan, garlic bread, green salad, Ranch dressing) and (DORITOS). Furthermore, there were three tasks that no one entered fully correct in HEI: a dinner (Meatloaf, mashed potatoes, lettuce salad, Thousand Island dressing, gravy, milk), that was also never correct in FBQI; and two breakfasts: (Bagel, cream cheese, latte) and (Breakfast burrito with eggs, bacon and cheese, apple juice, banana).

4.10.2.6.b BALANCE

Overall, we identified 23 errors, one of which was due to a technology failure. The remaining 22 errors were executed by 7 of the participants (the other 5 participants had no errors in this condition). 4 people had 1 error, one person had 2 errors, one person had 7 errors, and one person had 9 errors. The errors were of two types. First was a serving size error-the participant entered the wrong serving size. There were 3 instances of this error, and all 3 instances consisted of the participant entering “1.xx” servings rather than “xx” servings. This is a reflection on the design of the serving-size choosing interface. The interface defaults to “1 serving”. We can surmise that the participants probably just changed the “.xx” part of the serving size chooser, and ignored the default “1”. 2 of the 3 people who had this kind of error made no other errors.

The second kind of error was a substitution error, when the participant chose a similar food rather than the exact food. There were 19 instances of this kind of error. It is interesting that all of these errors resulted in foods that are very similar to the target food, but slightly different. Examples include “Spinach leaves” rather than “Spinach Salad”, “Iceburg Lettuce” rather than “Iceburg Lettuce Leaves”, generic “Swiss Cheese” rather than “Pauly County Line Swiss Cheese”. It is interesting that most participants with this kind of error only had 1 substitution. However, two participants had 7 and 9 substitutions, respectively. These two participants could represent a user profile of someone for whom “close is good enough” holds true.

4.10.2.6.c FBQI

24 errors were identified. 1 participant didn’t have any errors. The number of errors a participant had ranged from 1-4. 3 participants had 1 error; 4 participants had 2 errors; 3 participants had 3 errors; and one participant had 4 errors.

There were 4 types of errors we identified: Over-counting (counting too many in the correct category), Under-counting (counting too few in the correct category), Mis-categorizing (counting something that belonged in one category in a different one), and Non-counting (an entire category is not counted). There were 3 instances of mis-categorizing. In one case, a food that should be counted as a “Bread” was counted as a “Potato” (chocolate chip cookie). Once a “Milk” was counted as a “Cheese” (cream cheese or latte), and once a “Cheese” was counted as “Milk” (Swiss cheese).

There were 3 instances of under-counting. In these cases (B3, D3, B1), a category had 1 serving entered, rather than the expected 2 servings. The same participant counted a bagel as 1 bread serving, and a salad and broccoli as 1 vegetable serving rather than 2. The last instance of under-counting was when a participant entered 1 serving to cover 4 apricots and granola with raisins.

There were 8 instances of over-counting. All of the over-counting errors were counting 1 more than expected.

There were 7 instances of non-counting:

- No potatoes counted for ’2/3 c. mashed potatoes’
- No milk for ’latte’ (2 times)
- No bread for ’Wheat Thins’
- No veggies for ’peas’ and ’salad’ (2 times)
- No meat for ’pepperoni’

4.4.10.2.7 Likes/Dislikes After completing each condition, participants were asked to list 3 things they liked and 3 things they didn't like about each interface. Participants were given a free-text field to submit their answers, so all items were participant-generated. The lead researcher clustered the response. The process used was to: read through all items; identify clusters or group topics for each condition; attempted to identify similar clusters across conditions; put the raw items into the groups; collapse very similar items into a single item; count the instances of each item and each group. Because of the different nature of the index-based interfaces (HEI and FBQI) and the BALANCE interface, we were able to identify similar clusters for both HEI and FBQI, but not for BAL.

Overall, participants provided 94 (BAL=32; FBQI=34; HEI=28) items overall they liked about the interfaces, and 84 (BAL=26;FBQI=28; HEI=30) items they didn't like. Of these, 50 (BAL=20; FBQI=17; HEI=13) liked items and 43(BAL=10; FBQI=14; HEI=19) disliked items were mentioned by more than 2 participants.

The clusters that emerged:

Here, I describe each cluster and remark on the items within each cluster, but only the ones that were mentioned by 3 or more participants. 4.10.2.7.a Food Grouping

This cluster applied only to HEI and FBQI. It includes comments made about the food index and components. 4 participants noted that they liked the distinction of food group levels in HEI (the total versus whole countings), and 3 liked that more specific food groupings in HEI. However, they also noted that they didn't like that they didn't know how to categorize everything (which was not mentioned about FBQI) and that it was easy to forget to enter information about the nutrients (sodium, saturated fat, and the FAAS calories). With FBQI, participants (5) didn't like that not everything could be counted (for example, salad dressing), and they didn't like that it didn't include other measures for tracking such as calories or fat.

4.10.2.7.b Other

Participants (5) liked that BALANCE reported calorie counts, that it was quick to make estimates with HEI (3), and that FBQI was generally very fast (4).

4.10.2.7.c UI

This cluster included general remarks about what people liked or didn't like about the

Table 4.5: Overview of clusters/themes of like and dislike feedback

Row Labels	Dislikes	Likes	Grand Total
FBQI	28	34	62
UI	2	20	22
Food Grouping	14	2	16
Portions	9	3	12
Other	3	9	12
BALANCE	26	32	58
Search	10	7	17
Other	3	11	14
Servings	1	7	8
Hardware	6	1	7
UI	5	2	7
Software Features	1	4	5
HEI	30	28	58
Food Grouping	11	12	23
Portions	13		13
Other	2	11	13
UI	4	5	9
Grand Total	**84**	**94**	**178**

UI of the different interfaces. The only items that had 3 or more mentions were "general UI problems" with the BALANCE interface (5), and 10 participants mentioned that they liked that the FBQI interface was easy to read.

4.10.2.7.d Portions and Servings

Participants (5) commented that with HEI, it was difficult to figure out portion sizes, and it required too much reading. Furthermore, it was difficult to be exact with counting the servings or amounts (8). This is similar to an item reported about FBQI, which summarized that partial servings are hard (6). However, 3 participants did note that with FBQI, the portions were easy to estimate/calculate given the limited text and easy guidelines, and 5 participants liked that with BALANCE, exact amounts were easy to enter.

4.10.2.7.e Search

Since only BALANCE had a search feature, the comments only apply to BALANCE. 4 people reported that it was easy to find foods, and 3 people thought the partial search feature was good. However, 5 people didn't like that there were so many search results.

4.10.2.7.f Software Features

This might be able to collapse with the UI cluster. 5 people mentioned that they liked that they were looking for an exact food in the BALANCE interface. One other person made a similar comment that we counted separately, since it was more specific: they liked that they didn't have to think about what was in a food, they just had to find the food. One person also commented that they didn't like that the BALANCE condition didn't report anything other than calories.

4.4.11 Discussion

This study was designed to investigate the tradeoffs between three different approaches to food journaling. The three interfaces can be considered as belonging on a continuum: the BALANCE interface required a high level of detail; the FBQI required a low level of detail; and the HEI interface was in the middle. We expect that entering high level of detail on a mobile phone to be more time consuming, while less detail or more summarization would require less time. This was shown to be true: the time spent entering food in the BALANCE interface required significantly more time than HEI, which required significantly more time than FBQI.

However, an interface that is faster does not provide value if one is unable to capture the correct data, or perform the task correctly. HEI and FBQI, requiring less detail, require the user to perform some summarization and mental coding as part of the task. One research aim was to determine how difficult or time consuming this process would be. That is, one could imagine that for the index conditions, any time saved actually using the interface/mobile device would be spent thinking; the calculation is offloaded from the device to the human. We found that not to be the case (the time savings from reducing interaction with the device was much greater than any increase in thinking time, although we were unable to measure directly). We did find that the greater dependency on human processing impacted the correctness of the records captured in each condition, and it appears that participants noticed this, as reflected in the reported Successful and Mental Activity TLX measures. The HEI interface, which can be characterized as the most complicated and challenging of the three, resulted in significantly more errors than either BALANCE or FBQI.

The TLX surveys were administered for each condition to collect information about the participant's perceptions of the different interfaces. While our data shows the differences in time and correctness, user perception of the interfaces is an important part of whether the user will adopt a particular technology, and their level of comfort in continuing to use it. A user will not continue to use a technology if they are not convinced that it does the job, or if it requires too much work. The TLX responses show significant differences in participant reaction to the amount of mental activity the interfaces required, and how successful they felt in completing the tasks with the different interfaces. As mentioned previously, we expected that FBQI and HEI would require more cognitive activity/processing than the BALANCE condition, and this was evident in the Mental Activity measure on the TLX surveys. There was not a significant difference between reported Mental Activity required for FBQI and HEI, but there were significant differences between FBQI-BALANCE and HEI-BALANCE. The results are similar for Success. Participants reported feeling more successful with BALANCE, but not a significantly different amount of success between

FBQI and HEI.

Participants also ranked the different interfaces, in terms of overall preference, understandability, ease of use, and usefulness. If the interfaces were comparable, we would expect that each interface would be ranked #1 similar number of times. The only item with a significant finding was that of understandability. Based on these rankings, participants found BALANCE significantly more understandable than HEI and FBQI, while there was not a significant difference between HEI and FBQI.

Participants identified which interface they thought would help them reach their health and wellness goals. It is interesting that no participants thought that the FBQI interface would help them reach their goals. Based on the more detailed feedback reported in the likes/dislikes question, it seems that the FBQI simply does not account enough for foods people should restrict, and that it would be too easy to "fool the system", by specifically eating foods that can't be counted with FBQI (such as alcohol or salad dressings). Additionally, for people who have a more general goal of "eating better", HEI appears to be an attractive option. For people with more quantitative goals (losing weight, controlling portion sizes), the traditional BALANCE approach is still considered.

People can track their food with almost any food diary for 3 days. However, we're really interested in whether, with a bit of exposure, people believe that they will be able to continue with using an interface long enough to make a difference. The results are broken up based on whether the participant reported using a food diary before. This is because using a food diary consistently is a difficult task, and if you've done it before you may have better insight into your ability to use a new food diary for an extended period of time. I think it's interesting that of the people who have used a food diary before, they seem to believe they would be more likely to use BALANCE than the other interfaces. This could be explained because people who have used food diaries before have more quantitative health/wellness goals and don't believe FBQI/HEI will help them reach their goals.

The items that participants provided about what they liked and didn't like for each interface are valuable, as this is information that they volunteer. Most of the feedback consists of comments that are only applicable to a single condition or interface. Feedback on the BALANCE condition was expected, for the most part. The comments made are similar to comments made about BALANCE previously, and about traditional food journals in general. This included things like too many search results, which are difficult to sift through. However, items that are usually reported as a "dislike" in a similar tool (or are not mentioned/ignored) are reported as a "like" in this study, such as comments that foods were easy to find, and exact amounts are easy to enter. These comments could be in response to participants' experiencing HEI or FBQI first. After the reported uncertainty of HEI and FBQI, the certainty of BALANCE might be particularly compelling. It also reflects the lab study constraint of only including foods that existed in the BALANCE database. Using BALANCE in the real world usually results in more database misses, requiring the user to either enter the information manually (which is time consuming), or to not enter the information.

Participants provided many comments about the food groupings for HEI and FBQI. Participants specifically did not like that FBQI did not provide a means to categorize every food item, and there was no notion of calories or fat, or other nutrients to track. With HEI, participants didn't like that they didn't know how to categorize everything (and forgot to enter the nutrients), but appreciated the more specific food groups and the nutrients that people are frequently concerned about restricting (sugar, fat, salt). In both HEI and FBQI, participants seemed to like the overview provided and appreciated that the input was fast, however the portion or serving sizes was challenging and could be improved.

4.4.11.1 *Design Recommendations for Index-Based Food Journal*

Overall, I believe this lab study shows that there could be value in designing a new index-based food journal.

4.4.11.2 *Include Attainment As Well As Moderation Components*

Participants preference for HEI over FBQI and the feedback suggested that people understand that it's not enough to just count the food groups consumed. Avoiding or restricting some nutrients and foods, like sugar and alcohol, have major impact on one's health status. People want to be able to account for when they do consume those items.

4.4.11.3 *Provide A Tool To Count Specific Foods*

People aren't experts in either nutrition or food indexes. To support people in counting progress towards a food index, they need tools to help them determine how to count a food.

4.4.11.4 *Identify What Was Entered*

One problem that was identified was that people were sometimes uncertain if they had already entered a given food, particularly when entering tasks later in a condition (that is, the interface reflected that some foods had already been entered "earlier in the day").

4.5 Summary

In this chapter I identified research questions reflecting interest in further study of a mobile-phone based food diary that was not based on a food database. I identified and provided a review of food indexes, and described how a food diary based on a food index could provide value to users, particularly by being able to support goal setting and tending. I then described a lab-based study that compared food diaries based on food indexes (HEI and FBQI) to a more traditional food database based food diary (BALANCE). The lab study showed that compared to the food database approach, the food index-based approaches did take less time and mental effort to enter food items, and confirmed our intuition that they resulted in more errors. User feedback validated that one of the food index-based food diaries had perceived value, as well as the traditional approach. The study also confirmed that using a food diary in a controlled lab setting is not necessarily consistent with experiences in situ: user feedback also valued BALANCE, which is inconsistent with previous in situ studies. This allows us to conclude that while there could be value of an HEI-based mobile phone food diary in a real-world context, further studies need to be done.

Chapter 5
CONTRIBUTION 3: RESEARCH QUESTIONS AND THE DESIGN OF POND

In this chapter, I describe the design of POND, the Pattern-Oriented Nutrition Diary. In earlier chapters, I described the challenges and barriers that people face when employing a traditional approach to journaling what they eat, either on paper, a website/software, or on a PDA/mobile phone, and then characterized tradeoffs and preferences between traditional food journaling and index-based food journaling on mobile phones. Initial research indicated there could be a benefit for some people and some situations, although the lab-based research is unable to reflect the context and constraints that people encounter in the real world. In this chapter, I refer to the design considerations outlined in the previous chapter, identify specific research aims for evaluation a food index-based food diary in situ, and document the design of a mobile phone food index-based food diary.

5.1 Introduction

The Pattern-Oriented Nutrition Diary (POND) project is the result of the previous two studies. Participants in the BALANCE study taught us that looking up in the database was a challenge, and from the previous study that people in general preferred the HEI-based food diary to the FBQI-based food diary, due to the quality of information that it captured.

The goal of POND was to design and build a food diary that incorporated what we learned in the previous studies, and investigate whether experience the findings were applicable in the real world (as opposed to just a lab setting). Feedback from BALANCE participants indicated that they felt BALANCE required too much time and effort to make entries, and that they would be willing to sacrifice detail in exchange for an interface that was quicker and easier to use. The previous comparison study showed that while the FBQI-based interface was quickest and easiest to use, it didn't provide enough value in terms of the data/detail it collected. Participants were divided on whether they preferred the detail-oriented BALANCE interface, or the quicker-yet-still-valuable HEI interface to address their personal eating goals.

POND was designed to reflect the HEI. Initial user testing showed that people felt too uncomfortable entering the pattern directly for combination or prepared foods, so a food lookup feature was added. This used the NutritionistPro Knowledge Base [ref] food diary (as in the BALANCE and Comparison Study), and was intended to be used as an alternate entry strategy.

In the rest of this chapter, I first discuss the research questions we were looking to answer, then address some overarching design decisions that impacted the design of POND, and finally focus on the final design of the POND app.

5.2 Research Aims

The goal of this project was to design and build a food diary that incorporated what we learned in the previous studies, and investigate whether experience the findings were applicable in situ.

5.2.1 Primary Research Question:

Given a food diary that requires less time to use but provides less detail overall, will people use it "longer"?

5.2.2 Secondary Research Question:

- Will the ability to customize the interface to minimize it to the things you care about ("goals") impact the use of the tool?

- If the default interface contains items the users don't really care about, and are just taking more time for entry, do they get rid of them and keep tracking?

- Are people willing to minimize the tracking time?

- How/when/for what do people use the food database lookup feature?

5.3 Overarching Design Considerations

The instruments designed for the in-lab study comparing BALANCE, HEI and FBQI provided insight as to interface and interaction concerns, as well as ideas for how to make a food index-based food diary more useful. Here, I outline the concerns and suggestions, and identify how they impacted the design of POND.

5.3.1 Potential Challenge: Increasing entry time; combining analysis & entry on one page;

One key design strategy embodied in the HEI and FBQI interfaces was combining record entry and daily analysis mostly on one screen. This differs from the BALANCE interface, which showed an analysis or overview on one screen, and opened a different screen (or series of screens) for creating an entry. Since the goal of the project is to minimize the time and thinking that goes into capturing the food entry, it's important to think this through.

5.3.1.1 Direct Manipulation Versus "Fill Out A Form" Entry

Initial visions (and the in-lab research prototypes) were informed by the design goal of reducing the number of steps to create an entry. One can imagine an extreme end of this, where a visualization shows the current overview for the day, and as one drags a finger/-pointer across the visualization, the values change and an entry is recorded. Potential downsides include accidental entries and a greater learning curve. Additionally, the visualization needed to be able to adjust to the goal components and values changing over time.

An alternate approach is more similar to that used by BALANCE, in which a form pops up and needs to be filled out, item by item, and then the entry confirmed. This approach provides more guidance, but is also more time consuming and likely to be less convenient.

This was addressed by having each component represented by a widget that included a title, description, feedback, and entry button. The component widgets could then be added to the screen as desired, and the list of widgets could extend past the end of the screen. This approach is reasonable on modern smartphones, since a scrolling interaction is responsive, and expected by users.

5.3.1.2 *Quick-Add Versus Add-Earlier-Entry*

While POND is being designed in the hopes that people will use it regularly throughout the day, the fact is that sometimes, people will forget to make an entry. This was not a problem in the BALANCE software, as the add-entry screen included a widget to specify what time the food was eaten. Therefore, there was no difference in process to add a food either for now or earlier, but if a user was adding a food for earlier they would change that value. As mentioned in the previous section, for POND, we wanted to streamline the entry process as much as possible, and that meant not opening another window for creating entries. While this did streamline an entry for now, it required lengthening the process of making an entry for earlier.

5.3.2 *Potential Challenge: How to count a food*

The in-lab study showed us that people were uncertain about how to count a food using the food index. To ensure that their self-monitoring was beneficial, participants wanted more guidance on how to break a food into its index components.

5.3.2.1 *Looking Up Food Entries*

Initially, the POND prototype included explanations and examples for each of the components. However, initial feedback indicated that people really wanted some more certainty. This appeared to be particularly important when people were just becoming familiar with the counting approach. Therefore, we added a food lookup feature to the POND prototype. The lookup feature does not provide a perfect component profile for each food , due to the limitations of the database, but does provide some guidance.

5.3.3 Potential Challenge: Serving sizes

Serving sizes were an area of concern in the in-lab comparison study. Concerns included how to figure out how much was eaten, whether to round up or round down when counting a partial serving, and how much of something to count (for example, do I enter the slice of tomato on my salad?).

5.3.3.1 Serving Sizes

We addressed the serving size problem by referring to consumer-oriented literature developed by the USDA to educate consumers about the healthy eating guidelines [ref][USDA2010]. We ensured that the serving size amounts related to a real-world item to compare to. The amounts for the food group items were based on "typical serving sizes". For fruits and vegetables, it was cup, which was explained in terms of common servings (2 blocks is a serving the size of your fist, a small apple, etc); grains was in terms of cup (baseball, fist) or a slice of bread, pancake the size of a DVD, etc. Partial servings were supported by allowing the user to enter of a serving.

5.3.4 Potential Challenge: Not knowing if you've entered something or not

With the HEI and FBQI interfaces, observations of and feedback from participants in the in-lab study revealed occasional confusion over whether a food item was entered or not.

5.3.4.1 Time- And Location-Based Analysis

To address this problem we considered how we can automatically capture some context about the entry, and use that to help people decide if they entered either something they just ate, or something from a few hours ago. Entries can be tagged time and location automatically. We designed the interface to support tracking entries with user-defined locations. For times when the location can't be detected, all known (user-defined) locations can be easily chosen from a drop-down list on the front screen.

5.3.4.2 *Grouping Entries*

Another way we attempted to provide feedback about what entries have been made is to group entries together via time. Entries made within a certain amount of time (for the in situ evaluation, it was set at 45 seconds) were grouped together, and shown on the "daily history" list together, as opposed to separately. This is discussed in further detail later.

5.3.4.3 *Shortcuts/Combos*

Finally, we designed a "favorites" feature. This allowed users to define an entry themselves. A combination consists of a name (such as "Turkey Sandwich"), and the components that create it (2 whole grains, 3 proteins, 1 dairy, 1 sat fat, 3 sodium). When this is used for an entry, the name of the food is shown in the daily history list, which is described further later.

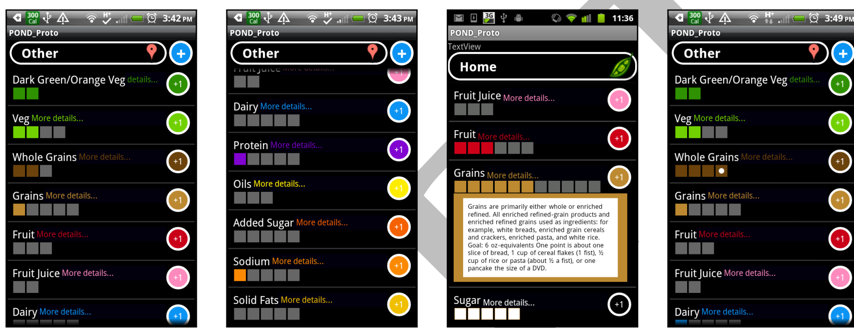
5.4 Design

The primary goal informing the design of the POND app was to minimize the amount of time it took to make an entry.

5.4.1 *Home Screen/Launch Activity*

The first screen the user sees when they launch POND is the home screen, shown in Figure 1. This screen was designed to prioritize quick entry and quick analysis of the current progress towards goals for the day. Each row represents a recommendation from the 12 USDA Dietary Guidelines we have described above. Users can touch the +1 buttons on the right side of the screen to quickly indicate a portion eaten, or long-press the +1 buttons to indicate a portion eaten. Colored links expand to show information about what counts in a given component (item), or what makes a serving. This information was adapted from the USDA 2010 Dietary Guidelines.

Location is indicated in a drop-down menu across the top. It automatically tries to determine which pre-defined location the user is in (Home, Work) or "Other" if it is an



(a) Viz1 (b) Viz2 (c) Viz3 (d) Viz4

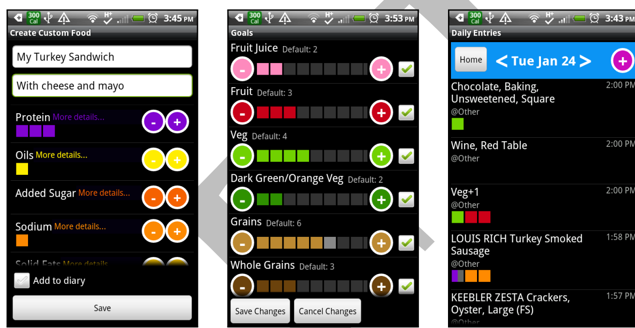
Figure 5.1: POND Screens.

unfamiliar location, and the blue "+" button opens the "Add Food" Screen. The phone's search button can also be used to launch a search widget and search for a given food.

For the components, dark gray boxes indicate the current daily goal for that component. A colored box indicates how many portions of that component have been consumed. A colored block with a white dot indicates that the user has consumed more than the goal number of blocks. The use of a white dot in the block was chosen in order to provide non-judgmental feedback about the amount of servings consumed.

5.4.2 *Daily Entries*

The "Daily Entries" screen was designed to show a list of the entries made over time so far today. The entries are reversed-ordered, with the most recent entry at the top. Here, users can distinguish between which items were looked up in the database versus which items were added with a +1. +1 Entries made very close together in time (15 seconds) are grouped together into one item, as they are usually connected. The entry is also tagged with the location. The purple + button allows users to go directly to the "Add Food" Screen, while the device search button opens up a search widget to allow the user to add a new item to the showing day's list. Different days can be viewed by using the arrow buttons at the top of the screen, or by swiping left/right. Touching one of the entries opens



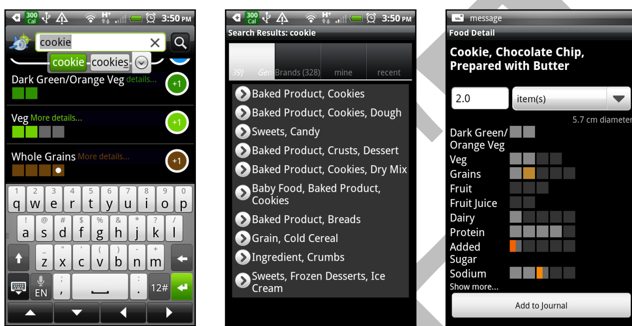
(a) Viz1 (b) Viz2 (c) Viz3

Figure 5.2: POND Screens.

up the appropriate "Entry Edit" screen and allows just that entry to be edited. A long touch on one entry shows a menu which allows the chosen single entry to be either edited or deleted.

5.4.3 *Create Custom, Frequently-Eaten Foods*

This screen supports the creation of shortcuts for food combinations that people frequently eat. Note, this is just a combination of "+1"s; not a combination of foods from the database, and it's intended to be a single serving (or, amount eaten at one time), as opposed to a recipe, which one might eat multiple or varying servings of. The example in the screenshot is a turkey sandwich: it's composed of two whole grains (for the bread), and if you scroll further down, some meat, some dairy, some solid fat for the cheese, some oil for the mayo, and some sodium for the bread, meat, and cheese. When the user then eats this turkey sandwich again, they can find it in the list of "My Foods" (description coming), and quickly enter it. The given, personalized name ("My Turkey Sandwich") is then shown in the list of entries made today as a named group of blocks. The "Add to Diary" button allows the user to create a new entry for both current and future use, while when the "Add to Diary" checkbox is not checked, it just saves it for future use.



(a) Viz1 (b) Viz2 (c) Viz3

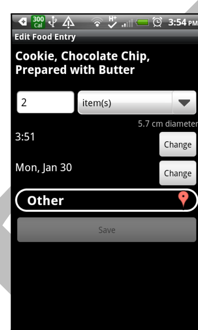
Figure 5.3: POND Screens.

5.4.4 Change Goals Screen

The change goals screen can be used to change which components appear on the front screen, as well as how many blocks appear for each component. The checkboxes on the right are checked "on" to appear on the front screen, and the +/- buttons are used to indicate how many blocks should be provided for each component. Default USDA suggestions are indicated. When the number of blocks for an item is less than the suggested number of blocks for a component, light gray blocks indicate how many more are needed to get to that amount. When more blocks are selected than the suggestion, the blocks have a white circle inside.

5.4.5 Search process/screens

Food from the database or custom created foods can be added from either a search or chosen from a list of foods used before. The device search button can be used to launch the search widget from either the home screen or the daily entries screen. The search term is used for a full-text search in the food name and manufacturer fields of the database. The results are broken into "Generic" and "Brand" tabs (as designated by the database). Within each grouping, if there are fewer than 100(?) results, the results are presented alphabetically. If there are more results, the results are presented in a two-level list, grouped by



(a) Viz1

Figure 5.4: POND Screens.

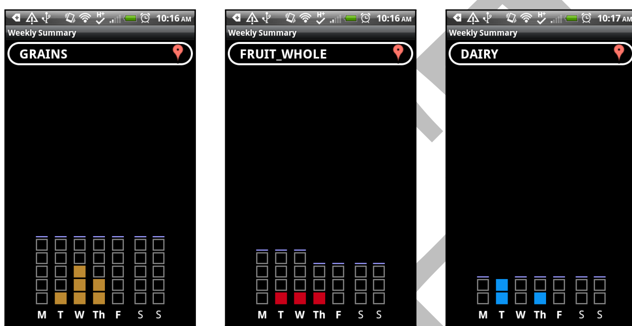
“Food Class”, as designated by the database, with the food classes ordered such that the class with the most entries is at the top of the screen, and alphabetically within the food class. From this page, the user can either “Refine” the search, or start a new search.

The other two tabs on this “Chose Food” screen include only foods that have been used before or have been created by the user. The “Mine” tab lists foods alphabetically, while the “Recent” tab lists the same foods by the order they were last used, most recent on top.

Once a food has been found and selected, the Food Detail screen shows more information about that food. It allows the user to change the serving size amount. The screen also displays how eating the specified amount of the chosen food will impact the goals for the day if eaten. The dark gray blocks represent the goal for that component, while the light gray blocks show what has already been consumed today. The colored boxes show the components due to the chosen food.

5.4.6 Editing Entries

There are two different Entry Edit screens: one for Food entries (from the database), and one for +1 or custom food entries (which are treated like a combination of +1 entries). For food entries, the user can pretty much just change the amount, time, date, and location of the item. For +1 or custom food entries, the user can edit the name (or give it a new, meaningful name) and add/edit/delete the components, as well as change the time, date



(a) Viz1 (b) Viz2 (c) Viz3

Figure 5.5: POND Screens.

and location of the entry.

5.4.7 *Weekly Feedback*

The weekly summary screen provides feedback about progress towards the goals throughout the week. The blue bars show the daily goal, or what that goal was for that day, empty boxes show that a goal hasn't been reached, while boxes extending past the bar show a goal that has been passed. Each screen only shows one component, and the drop-down list at the top (or swiping up/down on the screen) changes the component being displayed. Different weeks can be chosen via the menu, or swiping left/right on the screen.

5.5 Summary

In this chapter, I provided a detailed description of the POND food diary. The POND food diary was designed to require minimal resources in terms of time and decision making to capture dietary intake information. The design of POND was informed by user feedback and studies discussed earlier in this dissertation. POND was designed to represent the HEI, which received favorable feedback in earlier studies, and informed by information from the USDA's Healthy Eating Guidelines. The design of a food lookup feature was informed by experiences with the BALANCE studies. Reflections on the design are discussed in more detail in the next chapter.

Chapter 6

POND EVALUATION

Nothing here yet.

Chapter 7

FUTURE WORK AND CONCLUSION

Nothing here yet.

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Appendix A

WHERE TO FIND THE FILES

The uwthesis class file, `uwthesis.cls`, contains the parameter settings, macro definitions, and other TEXnical commands which allow LATEX to format a thesis. The source to the document you are reading, `uwthesis.tex`, contains many formatting examples which you may find useful. The bibliography database, `uwthesis.bib`, contains instructions to BibTeX to create and format the bibliography. You can find the latest of these files on:

- My page.

  `http://staff.washington.edu/fox/tex/uwthesis.html`

- CTAN

  `http://tug.ctan.org/tex-archive/macros/latex/contrib/uwthesis/`

  (not always as up-to-date as my site)

VITA

Jim Fox is a Software Engineer with UW Information Technology at the University of Washington. His duties do not include maintaining this package. That is rather an avocation which he enjoys as time and circumstance allow.

He welcomes your comments to `fox@uw.edu`.