The Food We Eat: An Evaluation of Food Items Input into an Electronic Food Monitoring Application

Katie A. Siek, Ph.D. [1], Kay H. Connelly, Ph.D. [2], Yvonne Rogers, Ph.D. [3], Paul Rohwer, M.S. [2], Desiree Lambert, M.S., R.D., C.D. [4], Janet L. Welch, D.N.S.[5]

[1] University of Colorado, Department of Computer Science, Boulder, Colorado, USA
Katie.Siek@colorado.edu
[2] Indiana University, Computer Science Department, Bloomington, Indiana, USA
{connelly, prohwer}@indiana.edu
[3] Open University, Department of Computing, Milton Keynes, MK7 6AA, UK
Y.Rogers@open.ac.uk
[4] Indiana University Hospital, Nephrology Dietetics, Indianapolis, Indiana, USA
dlambert@clarian.org
[5] Indiana University, School of Nursing, Indianapolis, Indiana, USA
jwelch@iupui.edu

Abstract. We present a formative study that examines what and how participants in a chronic kidney disease (stage 5) population input food items into an electronic intake monitoring application. Participants scanned food item barcodes or voice recorded food items they consumed during a three week period. The results indicated that a learning curve was associated with barcode scanning and participants with low literacy skills had difficulty describing food items in voice recordings. Participants thought this electronic self monitoring application would be helpful for chronically ill populations in their first year of dialysis treatment.

Keywords: Nutrition, Ubiquitous Healthcare, Pervasive Health Care, Chronic Illness, Self Monitoring, Quantitative Studies

1 Introduction

Researchers and clinicians use food diaries, 24 hour recalls, and food frequency questionnaires to gain a deeper understanding of what people consume [1-3]. However, these methods assume participants have good literacy and memory recall skills. In contrast many patients who suffer dietary problems and illnesses may not be able to fill them in because of their poor literacy and recall skills. For example, we work with chronic kidney disease (CKD) stage 5 patients who must rigorously monitor their fluid and nutrient consumption, but many of whom cannot perform simple calculations and have varying literacy levels [4] and are from low socioeconomic families. In general, these patients must limit themselves to one to two liters of fluid, three grams of sodium, three grams of potassium, and limit phosphorus intake. It is essential that they can find a way of managing their intake but traditional methods for nutrition monitoring have proven difficult for them to use. How can we provide an alternative method that they can reliably and competently use?

We are creating a mobile PDA application to help such chronically ill people monitor and maintain their nutritional intake. We chose to use a PDA because it has sufficient computational power and memory to create an application that can automatically compute and record dietary intake; a computer screen to easily show non-textual information; the ability to provide real-time feedback to patients to make improved decisions about diet on a prospective basis; and quick input mechanisms for patients to record information anywhere, anytime. For our application, we investigated the benefits and disadvantages of two alternative methods: (1) using a bar scanner to record the barcode on the food item package that is consumed and (2) using voice recording. Both methods obviate the need to read and write anything down.

In this paper, we present a formative study in the iterative development of our nutritional monitoring application. For this study, participants were asked to scan food item barcodes or voice record food items they consumed during a three week period. We wanted to identify what type of nutritional data people collect with an electronic monitoring application. More specifically, we were interested in:

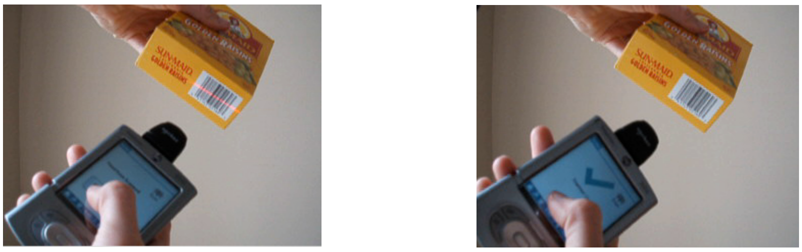
- The frequency of barcode scans versus voice recordings
- The types of food items participants input
- The ability of participants to accurately voice record food items
- Comparing what participants think they eat with what they actually record

The findings from our initial study suggest that there was a learning curve for participants to find, identify, and successfully scan a barcode. However, once participants learned how many foods had barcodes, they were more interested in voice recording what they consumed to decrease monitoring time. We also found that participants consumed foods specific to the low-cost stores closest to their homes, of which only 60% of the barcodes were readily available in the open source database we used. Our research showed that the participants with low literacy skills had most difficulty accurately voice recording food items for researchers to quickly identify. Overall, CKD patients and a renal dietitian thought the mobile recording application would be useful in monitoring personal nutritional intake.

2 Related Work

There are a number of software applications that are being developed to assist users in self monitoring their nutritional intake. The United States Department of Agriculture has a web-based and PDA nutrient database application that allows people to look up nutritional information of specific food items [5]. Intille et al. created a PDA application where people could scan two food items and compare the nutritional intake [6].

Other examples include DietMatePro [7] and BalanceLog [8] that use the USDA database along with other fast food nutritional information to create a PDA program that allows users to save consumption information for a set of specific nutrients. Dowell et al. gave three CKD patients DietMatePro to use over a three month period



(a) (b)

Figure 1 (a) Example of participant scanning food item with Socket Scanner. (b) Participant has successfully scanned a food item.

to see how nutritional consumption fluctuated with the use of an electronic diary. They found that the participants were within their recommended dietary limitations using the device; however participants were compliant before beginning the study. Their results indicated that the participants preferred using a large PDA screen with touch sensitive icons [9]. Sevick et al. had five CKD patients use BalanceLog over a four month period of time and found that nutritional intake was improved with the use of the electronic diary system [10]. Both of the applications described here require significant literacy and cognition skills.

Some research has begun looking at populations with low literacy rates use of PDA technology in health care administration [11, 12]. However there has been little research in studying how patients in low literacy, and low income populations can use technology to monitor their nutritional intake. Our study is unique because we are examining what type of data a low literacy and low income population input into an electronic nutritional intake monitoring application.

3 Methodology

In this section, we discuss why we selected the hardware and application used for this study. Detailed information about the experiment design can be found in the first author's dissertation [13].

3.1 Hardware

We chose an off-the-shelf Palm OS Tungsten T3 PDA for our study. The Tungsten T3 has an expandable screen, large buttons, voice recorder, SDIO slot, 52 MB of memory, and Bluetooth. A reason for using an off-the-shelf PDA was to enable the results to be generalizable in the UbiComp community for future studies.

The Socket In-Hand SDIO card scanner (Socket Scanner) was chosen as the barcode scanner because it was small, easy to use, and gave visual and audio feedback to users. As shown in Figure 1, participants must press the predefined scanning button,

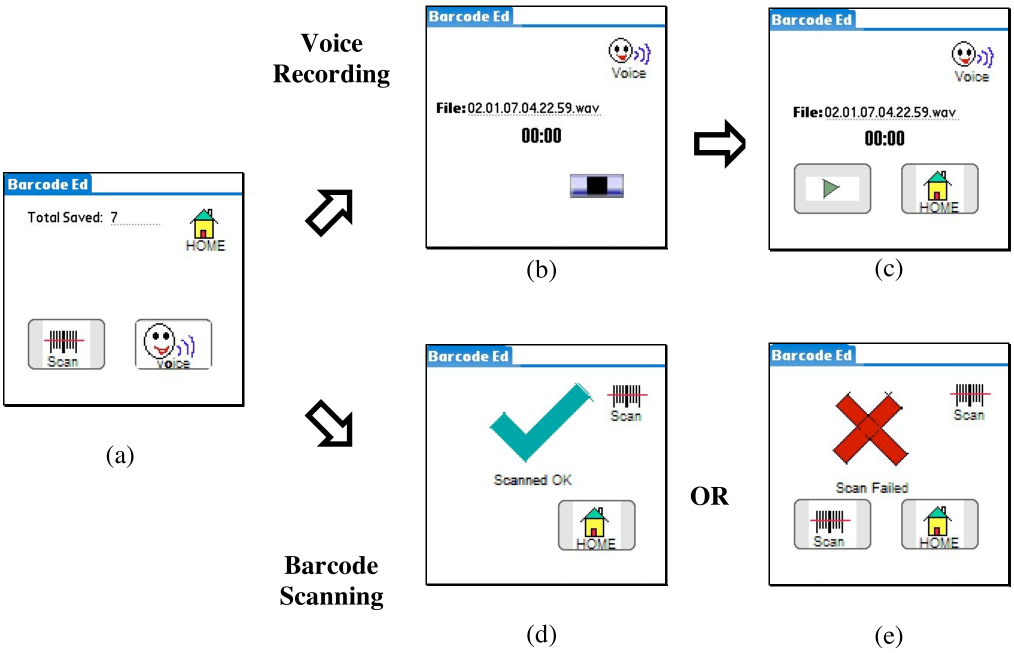


Figure 2 Screen shots from Barcode Ed. (a) Home Screen; (b-c) Voice recording and playback screens; (d-e) Barcode Scanning feedback screens

line up the scanning light perpendicular to the barcode, and hold the PDA and object steady. The PDA beeps and shows appropriate feedback when participants have successfully scanned a barcode. Previous studies have shown that CKD patients can use the Tungsten T3 and Socket Scanner [14].

3.2 Application Design

We created a simple application, Barcode Ed, because we wanted to isolate participants' ability to scan and yet have an alternative input mechanism (e.g., voice input) for participants to record *all* food items they consumed that may not have barcodes (e.g., restaurant food). In initial interviews, CKD patients said they did not eat any foods with barcodes. However, once they were prompted, we found they primarily ate frozen, canned, and prepared foods. Thus, in order for participants to use an easy input mechanism like scanning, they would have to learn how to identify barcodes and use the scanner. We only used scanning and voice recording in this iterative stage because we did not want to overburden novice computer users who have a history of decreased cognitive function [15] with a multiple screen interface.

Barcode Ed consists of five screens as shown in Figure 2. Since our user group had low literacy skills, we relied on icons 11mm large with some text for navigation. We found CKD patients can view icons 10mm or larger [14]. When participants turned on

Study Phase #	Length of Phase	Motivating Research Question(s)
Phase 1	1 week	1. Can participants find, identify, and successfully scan barcodes on food items?
Break	*3 weeks*	
Phase 2	2 weeks	1. Will participants remember how to use this application after a 3 week break? 2. Will participants actively participate without meeting with researchers every other day?

Table 1 Description of the two study phases.

the PDA, they would view the Home screen. Participants could choose to voice record by pressing the Voice button or scan a barcode by pressing the Scan button. As soon as participants pressed the Voice button, the application would begin voice recording and show participants how many minutes and seconds they recorded on the Voice recording screen. When participants were finished recording, they could press the Stop button and play back their recording on the Voice recording play back screen. When participants were satisfied with their recording, they could return to the Home screen. When participants pressed the Scan button, participants could see a red laser line emitted by the scanner. Participants lined the scanner line perpendicularly across the barcode they were attempting to scan. If the food item was successfully scanned, a green check mark would appear on the Barcode scanning success screen. If the food item was not successfully scanned, a red "X" would appear on the Barcode scanning unsuccessful page and participants could decide on whether to scan again or return to the home screen and voice record the item instead.

The application recorded the time the participant first pressed a Scan or Voice button, the barcode number or voice recording, and the time the recording was saved. We also recorded how many times participants played back their voice recordings. We did not record how many failed barcode scans were attempted because it was difficult to differentiate when a participant was scanning the same object or gave up and attempted to scan a new object during the same period of time. Also, participants sometimes did not use the scan button on the Barcode scanning unsuccessful page - instead they went to the Home screen and then pressed the scan button again. The times recorded assisted us in determining when participants recorded what they consumed. Recording the number of voice recording play backs gave us insight into how participants used the application.

4 Case Study of the Foods We Eat

The study required that participants complete PDA application training exercises, meet with researchers during dialysis sessions, and use the Barcode Ed application during two study phases for a total of three weeks. We were interested in learning if participants could identify and successfully scan barcodes for the first phase. Once we learned that they could use the Barcode Ed application to scan barcodes, we wanted to find out if participants would continue to actively participate in the study without as much interaction with researchers and if they could remember how to use the application after a significant break. Table 1 shows that there was a three week break between the two phases that allowed researchers to evaluate the data and decide on future directions for the application. All interactions with participants were done during dialysis treatment in an urban, public, outpatient dialysis unit. We documented how we conducted user studies in a dialysis unit in previous work [16]. In order to conduct this study, we received approval from the Indiana University Purdue University Institutional Review Board (ethics committee), nephrologists who treat the patients, the dialysis unit director, and the clinical manager of the dialysis unit.

4.1 Participants

Ten participants volunteered for the study that was to take place during their dialysis session. They had to be (1) over 21 years old, (2) able to make their own food or have the ability to go out and purchase food, (3) willing to meet with researchers during each dialysis session during the week, and (4) willing to carry the PDA and scanner with them and input food items they consume. During the first phase, one participant could not participate anymore because of a medical emergency and another participant dropped out because he did not want to record what he was eating (n = 8). Two more participants dropped out during phase two for similar reasons (n = 6).

The average age of participants was 52 years old (s.d. = 16.3). Half of the participants were male; seven participants were black and one participant was white. Two participants completed associate degrees, five participants graduated from high school, and one participant completed 10th grade. Participants had been receiving dialysis treatments on average of five years (s.d. = 3.5 years).

Four participants reported using a computer. Usage frequency ranged from every couple of months to once a week for a half hour. Participants primarily played games and played on the Internet. Two of the participants owned a cell phone that they used for emergencies only.

Participants described having good and bad days depending on when they had dialysis. During bad days, participants reported they typically had 1.5 meals accounting for three food items. During good days, participants reported they typically ate two meals accounting for five food items. The participants were equally divided about how many food items they consumed had barcodes - some thought all of the food items had barcodes and some did not think any food items had barcodes.

Five patients initially said they did not have to monitor any nutrients or fluid. However, by the end of the first phase, all participants admitted they had to monitor fluid and nutrient(s) such as sodium, potassium, phosphorus, and protein. None of the patients recorded their fluid or nutrient consumption prior to the study.

4.2 Design and Procedure

We met with participants during dialysis sessions four times during each phase of the study for approximately 30 minutes. During the first session, we collected background information and taught participants how to turn the PDA on, insert the scanner, and use the application. Participants practiced scanning various food items and voice recording messages. Researchers met with participants during the study sessions to discuss any problems participants may have had with the PDA, retrain participants how to do certain tasks (e.g., barcode scanning), and collect recordings and barcodes from the PDAs via Bluetooth. The researchers played back the voice recordings to ensure the correct information was transcribed and advised participants if they voice recorded a food item that could have had a barcode. Participants returned the PDAs at the end of each phase of the study, talked to researchers about their experience, and verbally completed a modified Questionnaire for User Interface Satisfaction (QUIS) [17] survey.

Competency skills tests were administered at the end of the second and fourth meeting of the first phase and during the first and last meeting of the second phase to test basic Barcode Ed skills - turning the PDA on; inserting the scanner; scanning three to five objects with different physical qualities; voice recording with play back; and completing a combined barcode scanning and voice recording sequence. The items participants had to scan ranged from a cardboard soup mix box that is easy to scan because of the material; a can of chips that is somewhat difficult to scan because of material and barcode orientation; and a bag of candy that is difficult to scan because it is amorphous and made of shiny material. We measured how many times it took participants to successfully complete each task and the time it took to complete each competency skill with the Barcode Ed application.

Participants were instructed to attempt to scan the barcodes on food items first and only voice recording items if they could not scan the barcode or a food item did not have a barcode. When participants mastered scanning and voice recording, we encouraged the participants to note via voice recording how much they were consuming and the portion size. Each participant was given a phone number of a researcher to contact if they had any questions during the study. Participants were given a simple visual diagram of the application to assist them with any questions they may have about how to use the application that had images similar to those shown in Figure 2.

5 Findings

The key findings of our study were:

- Participants preferred voice recording once they mastered barcode scanning and voice recording inputs
- Participants barcode scanned items from specific discount stores of which 40% were not in our open source database

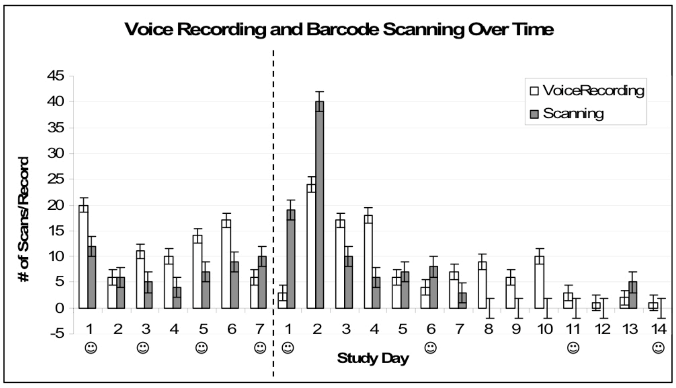


Figure 3 Graph of the number of voice recordings and barcode scans participants input over the two barcode education study phases (dotted line denotes study break). Faces underneath each day denote when researchers met with participants.

- Participants with low literacy skills needed extra instruction on how to describe sufficiently food items for voice recordings
- Participants reported more individual food items with the Barcode Ed application than what they thought they consumed

In the next section, we present the results in more detail. We summarize the findings from a QUIS questionnaire and present charts detailing the times of participant's consumption in the first author's dissertation [13].

5.1 Barcode Scanning and Voice Recording Frequency

One of the motivating factors for the first phase of the Barcode Education study was to teach participants how to identify and scan barcodes. In Figure 3, we see that there was a learning curve associated with identifying and scanning barcodes during the first study phase. Participants voice recorded more individual food items during the first few days of the study because they were either unsure of where the barcode was located on the food item or were unable to scan the barcode. Gradually during the week, we noticed an increase of barcode scans until the last day of the first study phase when participants barcode scanned more than they voice recorded.

A goal of the second study phase was to see if this trend of increased barcode scans would persist and if participants would continue actively participating in the study without meeting with researchers every other day. The first two days of the second study phase were promising because participants were scanning everything they consumed and only voice recorded items without barcodes (e.g., fresh produce). However, after the second day, participants realized *everything* had barcodes and were overwhelmed with the amount of time it took to scan every individual food item.

Thus, during the third and fourth day of the study, participants began voice recording food items they had previously scanned to save time.

During the second week of the second study phase, participants rarely scanned barcodes and typically voice recorded what they consumed. The voice recordings listed multiple food items in an unstructured manner. For example, one participant recorded, "I ate a small apple, a lunch meat sandwich, and a boost for lunch. I ate Cheetos, eggs, and bacon for breakfast. Tonight for dinner I am planning on eating…"

When we asked participants why they scanned more on the 13^{th} day of the study, they told us that they had remembered they would see a researcher on the following day to finish the study, suggesting our impending visit had a strong motivating effect.

5.2 Identifying Barcodes

We attempted to identify each barcode participants input with the Barcode Ed application to help dietitians and clinicians learn what participants were consuming. Since there is not a freely available barcode database available, we used the Internet UPC Database [18], an open source database containing 622,363 identified barcodes. Anyone with Internet access and an email address can register and input barcodes and associated product information. We were only able to identify 60.29% (s.d. = 31.77%) of the barcodes input by participants with the open source UPC database.

5.3 Voice Recording Food Items

We thought voice recording food items was an easy alternative, backup input method when participants could not scan. However, participants with low literacy skills were initially unable to give sufficient identifying information in their voice recordings. Since the participants were unable to read the name on the food item, they were not able to say what they were eating (e.g., Lucky Charms cereal). Instead, participants said, "I had cereal for breakfast." When we met with participants and played the recordings for transcription, we were able to suggest ways for the participant to be more descriptive (e.g., describe what is on the box) to assist us identify the food items. After two to three sessions, the low literacy participants recorded more descriptive input (e.g., I ate the cereal with the leprechaun and rainbow on the box) and it was easier to identify what they were eating. However, even with descriptive input, we were unable to identify three of the items mentioned in the 195 recordings.

5.4 Barcode Ed versus Self Reported Food Items

In pre-study interviews, participants told us they had good and bad days that affected how much they consumed and discussed how many meals they typically consumed on each of these days. The participants usually had a good and bad day fairly recently and could easily describe to us the exact number of items they consumed. We asked participants if they had a good or bad day each time we met during the first study phase. We then compared how many items they electronically input to how many items they said they would consume including the type of day they were having in the calculation. Participants ate more than they estimated for an average of three days (s.d. = 2.875) during the seven day period. When participants did consume more than they estimated, they typically consumed on average 3.5 more items than estimated – nearly doubling their normally recorded intake of 4.4 items (s.d. = 3.27)[1].

6 Discussion

Even though barcode scanning is a quick method for inputting individual food items, our results show that it is not usable over an extended period of time. Participants were overwhelmed with the amount of work associated with scanning every food item they consumed. However, participants did think that this application would be helpful for CKD patients who have recently been diagnosed with the chronic illness to assist them in learning about the strict diet. Participants thought CKD patients in their first year of dialysis treatment would be more likely to spend extra time scanning barcodes if it meant clinicians could give them better feedback about their diet and health. Another possibility for an electronic self monitoring application would be to have people use it periodically (e.g., quarterly when dietitians are conducting nutritional assessments with patients) to raise awareness and help them stabilize their diet.

We acknowledge that Barcode Ed does not query participants about portion sizes, but this was not the focus of the study. Future research needs to be done with low literacy populations about how to visually present portion size information. The participants in our study learn about ideal portion sizes when they meet with renal dietitians. However, we noticed participants did have some confusion about portion sizes and the types of food they consumed.

Identifying the barcodes participants input was difficult for us because we used an open source database. Identification may become easier as the database is propagated with more data, however this may be a socioeconomic resource issue. Those who contribute to the open source database have high literacy skills and resources (e.g., a computer and the Internet). Most likely the database contributors do not shop at the same stores as this population. In the future, we may be able to buy a complete barcode database, but the authors question database completeness after visiting the stores the participants frequented and found food items with what looked like home-made, self printed barcodes.

Participants voice recorded some items (e.g., cereal boxes) even though they had previously scanned the food item because of the physical properties of the item (e.g., cereal box bulk). The scanner had to be held approximately six inches (15.24 cm) from the food item, thus making it awkward to scan larger items. Once participants

[1] The standard deviation is large because it depends if participants were having a good or bad day in terms of consumption and physical health.

began voice recording items they formerly scanned, they began recording more food items in a single recording. Indeed, five of the participants preferred voice recording to scanning during phase one. Unfortunately, unstructured voice recordings are difficult to automatically parse and require a lot of time from the researchers to transcribe. More research is needed in alternative input mechanisms for low literacy skilled populations. We are currently working on a structured voice input system for food intake monitoring.

We did not anticipate the amount of training participants needed in order to create descriptive voice recordings. In retrospect, it made sense that people with low literacy skills would not be able to gather enough data from the food item to identify it. Transcribing the data was time consuming, but was easier as the study continued because the participants typically consumed the same food items. Researchers need a better understanding of their user group so they can accurately identify food items that may be culturally or economically influenced. Since our user group has a very strict diet, not being able to identify food items is unacceptable since it can have such a drastic change in participants' diet.

Participants' underestimation of what they thought they would consume in comparison with what they actually consumed has been documented by other nutrition researchers [1, 2]. However, electronic self monitoring gives more detailed information (e.g., date, time, food item) than 24 hour recalls and food frequency questionnaires as had been used in the previous studies. Indeed, the standard deviation for the days participants ate more than they estimated is large for our small sample. This is significant because of the participants' strict diet – over consumption of the restricted nutrients is dangerous to their health and can result in death. In future work we will look for correlations between what people report they eat in electronic self monitoring applications and 24 hour recalls to see how it effects their health.

7 Conclusion

We have presented a formative study that examines what and how participants in a chronically ill population input into an electronic intake monitoring application. Participants with chronic kidney disease, most with low literacy skills, were asked to scan food item barcodes or voice record food items they consumed during a three week period. We found that there was a learning curve for participants to find, identify, and scan a barcode. Participants preferred voice recording in order to decrease the burden of self monitoring. A more complete barcode database is required to identify all food items participants input via barcode scanning. Participants with low literacy skills had difficulty accurately describing voice recording food items for researchers to quickly identify. More research is needed in the area of alternative input for nutritional monitoring applications in order for populations with strict diet regimes to quickly and easily self monitor what they consume.

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