

Mobile Computing in the Retail Arena

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ABSTRACT

Although PDAs typically run applications in a “stand-alone” mode, they are increasingly equipped with wireless communications, which makes them useful in new domains. This capability for more powerful information exchange with larger information systems presents a new situated context for PDA applications, and provides new design and usability evaluation challenges.

In this work we examine how grocery shopping could be aided by a mobile shopping application that consumers access via a PDA while in a store. The interactive relationship between the physical space of the store and the human activity of shopping are crucial when designing for this application. To better understand this interaction, we studied people's grocery shopping habits, designed and evaluated prototypes, and performed usability tests within the shopping environment. This paper reveals our design process for this problem and a framework for designing and evaluating situated applications for mobile handhelds.

Keywords

PDA, mobile interfaces, situated computing, wireless communication, user-centered approach, interactions

INTRODUCTION

Hand-held computers and personal digital assistants (PDAs) have largely been used for a few narrow tasks: scheduling, calendar management, and list keeping are some of the most common ones. However, as more PDAs acquire wireless connectivity capabilities, a new set of potential uses is exposed. We became interested in exploring the use of PDAs in retail shopping situations, more specifically, in grocery stores. The biggest advantage of the PDA is its portability and how well it works for organizing and presenting information. These characteristics are appropriate for the task of shopping.

Until recently, commercial grocery shopping aids were hard to find. One of the first shopping applications for the PDA that we encountered was simply a list management tool allowing users to input and select items for a grocery list. The application provided little more than a physical list and provided no assistance in the act of shopping.

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Within the last year or two, numerous shopping aids have emerged, from on-cart devices to applications for handheld devices. Easi-Order™ is a PDA application for use in the home that focuses on the creation of a personal shopping list that can be sent to the grocery store [1]. This application has been launched in Safeway stores across the UK. Klever-Kart was designed by Klever Marketing, Inc. to bring “interactive advertising to shoppers directly at the point of decision” [5]. Klever-Kart is an on-cart device that offers users in-store information such as sale items, nutrition information, news and weather. Finally, Andersen Consulting developed an application called Shoppers Eye that “addresses the problem of shoppers’ lack of awareness of buying opportunities” [3]. The user carries a handheld in a shopping mall and the system makes their shopping list available to local stores, which in turn make bids for the user’s business.



Figure 1: A grocery shopper using a PDA

How do mobile devices such as these affect the shopping experience? Is a PDA potentially beneficial for a shopping environment? Because there are obvious limitations to PDAs such as the display size, resolution and difficulty of input, we speculated that most handheld devices used in mobile situations would only be appropriate for on-the-go lookup activities.

We wondered how a shopper would shop while holding a device, as shown in Figure 1. Because shopping in any capacity almost always requires the use of hands, form factor is extremely important in mobile computing. We felt that focusing on the task of shopping; learning how people determine what they need and how they obtain it, would be an appropriate first step into exploring how a PDA could interact with a larger in-store information system.

Our design focuses on a real world application of mobile computing carried out in a retail environment. Once in the retail environment, the wireless network creates a “digital space” where information is sent to the user’s PDA contingent on their shopping list. The digital space provides context for the user with task specific information, and thus a computational environment to support grocery shopping.

This paper discusses our process for designing a wireless application for a PDA with regard to the human interactions and situations in the realm of grocery shopping. First we describe our initial observations and study of numerous shoppers and how they act in the retail space. Next, we discuss how we undertake designing and evaluating the interactions of a mobile interface. And finally, we describe the initial prototype developed and the results from an in-store evaluation.

We utilize ideas from situated computing [4] and discuss evaluating and designing an interface for a mobile application. We assume a technological infrastructure exists to support the overall system. Tradeoffs and decisions made for designing and evaluating an application prototype for a handheld device are included in the hopes that this study may provide others with assistance for developing these types of applications.

HOW DO PEOPLE SHOP?

When a consumer enters a grocery store their intention is to buy products. Unlike other forms of shopping, people do not generally “window shop” for groceries. Our early investigations to uncover how people grocery shop involved three main directions:

1) Observe people while they shop. How is it that people maintain their needs? Do they use a list or do they wait for the context of the store to drive their needs? Or does some combination hold? To answer these questions, we anonymously observed shoppers in 3 different grocery stores.

2) Shop with people and ask questions about their shopping as it unfolds. This ethnographic approach offered very valuable insight. We followed 5 participants throughout the task of shopping. Shopping is a repetitive task and it was easy to see people’s shopping habits emerge, especially in a grocery store with which they were familiar.

3) Ask people how they shop. We designed a survey with a set of wide-ranging questions on topics including shopping frequency, list making, habits, etc.

46 participants responded to the survey. We asked questions about shopping, technology usage, and potential features for a grocery application. Participants ranged in age from early 20s to mid-60s with a mix of single, married, working, retired, and with or without children.

When presented with features of a possible grocery shopping application, participants ranked them in order from highest to lowest priority: 1) Create a grocery list, 2) Arrange a grocery list, 3) Provide product location by aisle, 4) Itemized pricing, 5) Specials and coupons, 6) Electronic

checkout, 7) Within store price comparisons, 8) Map of grocery store, 9) Recipes and ingredients, 10) Health information, 11) Product information.

This survey also allowed us to glean device preferences among participants. We found that although 83% of our population used a mobile phone (only 26% used a PDA), they preferred a PDA as the form factor for a shopping application. People felt that they could trust their personal PDA more than a device provided by the store. They thought that it would give them flexibility between home and store usage. These responses were worth further investigation because, in their explanations, many participants made assumptions about the functionality and form factor of the product even though it did not yet exist.

The survey, interviews, and observations provided us with a wealth of information from which we garnered some obvious but latent facts about how people shop. Basically, two kinds of shoppers emerged, those who make physical lists and those who make mental lists. We did not find a single person who did not at least make some type of mental or physical notation for items they needed before entering a grocery store.

This led us to wonder what happens to the physical grocery list while shopping. How is it used? Most often the list is carried on the person (in-hand or in a pocket) throughout the store. Others leave the list in the cart as they retrieve items. About half of the people who carry a physical list mark off items as they shop. This is noteworthy because it shows that people sustain interactions with their grocery list in the midst of shopping.

On the other hand, those people who make mental lists tend to rely more on the grocery store environment to either inspire or remind them of items they might need. Therefore, browsing was the main catalyst for obtaining their grocery needs.

In our observations we discovered one of the most important factors in the mechanics of shopping: *shoppers must use their hands*. People require their hands and eyes to look and feel for fresh and ripe produce. They must pick up packages and read labels. Grocery shopping is an especially hands-busy, eyes-busy task. As Underhill states, “it’s hard to overemphasize the importance of the hand issue to the world of shopping...if the shopper can’t pick [items] up, it’s all for naught” [8].

The Retail Environment

The motivation of a retail store opposes the user’s intention; a retail store wants shoppers to spend as much time as possible in the store because this can directly translate to more sales. The longer a shopper is in a store, the more likely they are to buy something [8]. According to market research, almost 60 % of all products bought at the grocery store are not premeditated purchases [2]. Underhill’s fieldwork techniques present the environmental psychology behind public spaces and reveal how important the store and the aisle are to the total shopping experience.

At an early stage in our analysis we too realized the importance of this physical space and began to deconstruct the arranged space within the grocery store.

In our initial fieldwork we observed three major grocery stores, analyzing the layout and product location within the store. We found that most of the time the general location of products were the same across stores with only the end caps displaying varying contents. A grocery store is an overwhelming repository of information in the form of visual, tactile, aural and olfactory stimuli. There are signs, labels and prices to read, produce to squeeze and items to grab from shelves. In addition there are noise factors, scanners beeping, cash registers buzzing and carts rolling. Music is playing, and announcements are being made while conversations are taking place. All these factors serve, even implicitly, to keep the shopper in the store and influence their spending.

As Nardi points out, it is not the store or the individual shopper that require analysis but, instead, the relationship between the two [7]. In the store, the shopper is presented with an enormous retail environment that they must “edit” according to their task at hand. According to Lave, a shopper in a grocery store experiences the store as a “personally ordered, edited version” of the larger store [6]. A shopper may shop “only for certain items in certain aisles, depending on needs and habits.” Thus the store has been “edited” to “match personal preferences” [7]. We refer to this as the edited space.

Our research supports the notion of an edited space, even more so when the shopper is engaged in interacting with a mobile interface. As mentioned earlier, grocery shopping is a “hands-busy, eyes-busy” task. Shoppers are already so involved in finding what they want that adding PDA interactions may create further distractions and further editing of the store. Any design in this area must carefully consider this fact.

The Shopper's Profile

We studied many varied shoppers, single and married, male and female, mixed in age. We found innumerable characteristics of shoppers across a range of demographics. Lifestyle emerged as a relevant characteristic because it determines how people shop. If a shopper is purchasing groceries for a household, the list may be a collaborative effort where communication is important. If a shopper is on a budget then coupons and specials become relevant to their buying decisions.

In general people shop in grocery stores with which they are familiar. In our survey 72% visit the same grocery store due to convenience and familiarity of store layout. It is a special case if a person shops at a grocery store they do not frequently visit. Similarly, shoppers tend to navigate the store using the same route.

Since grocery shopping appears to be based on lifestyle and personal preferences, no one specific pattern of shopping emerges. It seems that the profile for a grocery shopper

cannot be whittled down into one succinct description. Therefore, we developed a high-level profile of a shopper who might benefit most from a mobile shopping aid. This profile involves a person who would frequent the same grocery store and use a “loyal shopper” card.

Grocery stores attempt to lure shoppers through various sales, specials and offerings including “loyal shopper” cards. Specifically, these cards entitle the bearer to numerous items at a lower price than those who do not have a card. While shoppers believe that the cards are a “gimmick”, many still use the cards when they grocery shop. The use of these cards enables the grocery store to track what and when an individual buys.

MOVING FROM TASK TO DESIGN

What tasks in the shopping process could be aided by a mobile context? Answering this question required studying the physical task of shopping as well as people's internal objectives. Common among shopping are three separate high-level tasks; pre-shopping, in which a person plans or decides to go shopping; shopping, where the person is actually in the store shopping; and checkout, where the person makes payment for the items and leaves the store.

The time spent in preparation outside of the store is contextual and results in a list being created whether it is physical or mental. It can be a collaborative effort or a last minute solo act prior to visiting the store. Regardless, the result is the creation of the shopping list.

While shopping, we found that shoppers want more knowledge, control, and convenience. In contrast the retail industry constructs the store environment to move a shopper in a contrived route, having constructed zones to influence the intentions of the shopper. These competing goals and the complexities of the act of shopping offered more possibilities for designing the relational interactions between the store and the shopper. Therefore, we decided to focus our design on the actual act of shopping.

Our observations within the store revealed that most people have a good understanding of the store environment and how to act in it. “The integration of human-computer interaction and the user's situation in a particular working context in a mobile environment is identified as the situated interaction” [4]. Situated interactions, where the user utilizes the interface while shopping, became the greatest challenge for designing the mobile interface. We were challenged with identifying appropriate times of interaction where a situated application could offer assistance to the user while shopping.

During the task analysis, we uncovered breaks in the shopping task where a situated application could complement the task at hand and assist a person with just-in-time information. For example, one break could happen while searching for a product in the store, or trying to remember an item to purchase. The application at this point would provide a clue or reminder specific to the situation.

From the task analysis of shopping, and the user-preferred features, our design criteria emerged. Top on our list was to develop interactions in the mobile interface, which complement the situations that users encounter while shopping. The grocery list became the cohesive force for achieving this criterion. The grocery list is the key artifact used within the system of grocery shopping because it is a representation of the premeditated intentions of the user while in the store. By creating a shopping list, a person has specified particular situations for the context of shopping. The presentation of a list on the PDA merges the interface into the context of the store.

Early Ideas and Concepts

In order to ensure that we thoroughly canvassed possible design ideas, an early design activity focused on creating scenarios in which a PDA shopping application would be useful. The scenarios were wide-ranging and were motivated by real shoppers who described how it is that they shop, what frustrates them about grocery shopping and how their shopping could be improved. Eventually, we sculpted a final scenario that could possibly be implemented today and offers many of the features that shoppers want most.

In the scenario, the local grocery store contains an “always-on” information system. The shopper, who is a member of the local grocery store’s frequent shoppers club, would be immediately recognized upon entering the store.

There are four types of lists the shopper can use:

- 1) A grocery list from the store based on their previous purchases. This list is generated by the store and is created based on the frequency of the shopper’s past purchases. A shopper who frequents the store on a regular basis enables the store’s information system to predict their grocery needs.
- 2) A personal grocery list created in the home.
- 3) A grocery list that family members have phoned in or interactively paged to the system. When a shopper joins the club, a profile can be created for every person the shopper cares to include. Therefore, those items that family members need or items that, for instance, are remembered in the middle of a meeting, can be captured as they are thought of.
- 4) A combined list of all three. Those items that may be duplicated across the lists are consolidated and one master list is created.

The availability of these different lists attempts to reach all types of list-makers. Those who currently make grocery lists can still do so using the application. Those who do not make lists are also catered to through the store-generated list. And for those who want to ensure they have gotten everything they need in one trip, the master grocery list serves them best.

Once the shopper enters the store, the list is reordered to provide the most efficient route to obtain every item on the

list. Shoppers can shop for the items on the list, check off items as they acquire them, review and add specials to the list, view and save recipes and watch for in-store coupons and specials. Preferences would allow the user to modify these features.

Upon checkout the shopper scans the grocery items and the system compares the original list with the items that have been scanned. An updated “scanned” list is beamed to the PDA allowing the shopper to verify the total of the grocery bill. When satisfied with the purchases, the shopper can beam the absolved list along with payment information back to the checkout. A receipt is beamed back to the PDA for the shopper to later reconcile with a checking account.

One of the resounding complaints we heard from participants was that checkout lines were too long and that waiting in line to checkout was the worst part of grocery shopping. Although the scenario addresses this issue, alleviating the checkout line would be another research project in and of itself.

Design Evolution and Rationale

The scenario in combination with our task analysis prepared us for the next stage, in which our concepts were interpreted into a visual language, the interface. We attempted to merge the features from the design scenario with the appropriate mappings and interactions from the situated space into a mobile interface.

We presented three interface designs to a focus group session for feedback. While the first design reflected a basic Palm OS application, our second and third design attempts were more appropriately focused on the spatial and contextual aspects of shopping.

The spatial design, shown in Figure 2, incorporated a store map that displayed icons to show where items on the grocery list were located. This idea was well received; however, the store map commanded most of the screen real estate, resulting in problems with occlusion when other features of the interface, such as coupon alerts or search functions, appeared in pop-up windows.

The contextual design, shown in Figure 3, served two purposes. In a person’s home, the interface served to aid the shopper in creating a shopping list. Therefore, the interface was divided in to four portions: a refrigerator, a kitchen pantry, a utility closet and an “additional items” area. Since we discovered that lists were created contextually, these four segments provided context for the shopper when identifying items needed at the store. Once in the store, the interface retained four segmented areas, but they were now divided into a store map, a promotional area, a grocery total and the grocery list created at home. This interface had its merits but sacrificed some of the spatial design’s features such as the size of the store map and the location of the items within it.

The focus group helped us to advance through the first iteration of an interface. Continuing to balance the data gathered from our survey and observations with the

feedback from the focus group, we redesigned the interface. It is at this point that crucial design tradeoffs occurred. Our redesign is shown in Figure 4.

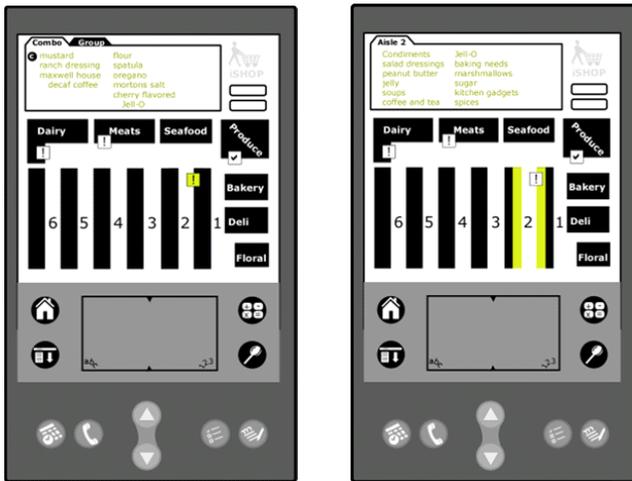


Figure 2: The spatial design

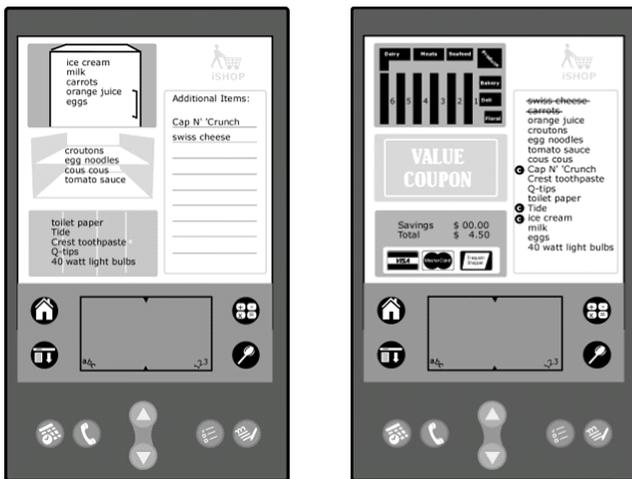


Figure 3: The contextual design

Clearly, PDA displays have extremely limited space. The merging of the desired features from both the spatial and contextual interfaces presented design obstacles. We would have to use pop-up windows that would, at different times, occlude the main interface. Designers for handheld devices refer to this as “deck stacking”. It is a metaphor commonly used on small screen real estate.

In the task of shopping, people’s priorities are the list of items they need and knowledge of where those items are located. Therefore, we left the grocery list at the top of the screen and devoted the center of the screen to a store layout. This redesign required a heavier use of icons due to limited display area. The revolving promotional area was moved to the bottom of the screen so that the user could continue to be informed and take advantage of store coupons and specials.

We mocked-up this design into nine screens for a paper prototype, and evaluated it for the information architecture

and visual encoding. Of the 8 participants, 7 were not PDA users and 5 did not routinely make physical grocery lists. For the evaluation a moderator walked the participants step by step through a shopping scenario. The overall system was described and each participant was shown two or three screens at a time (depending on the actions taking place on the interface). They were asked what action they would take on the interface to complete the intended task. Along the way the participant’s thoughts and suggestions were encouraged.

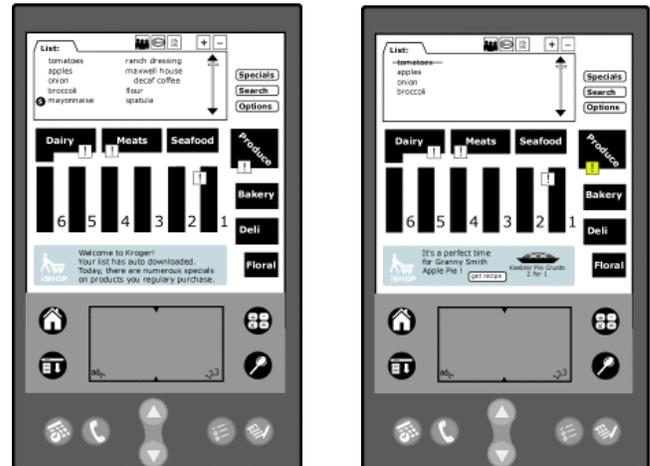


Figure 4: The formative evaluation redesign

The evaluation uncovered several interesting items. Perhaps the most important was the fact that participants who were unfamiliar with how to use a PDA offered mixed responses. On one hand they could not “traverse” the interface in a manner required when using a PDA. As a result, they limited their actions to what they knew they could do with a mouse on a computer. On the other hand, because they were not limited by knowledge of how to interact with PDAs, they offered insight through their interpretations and comments. Additional findings were:

- Locations of interface functions (buttons or icons) needed closer proximity to the objects or areas on which they take action. For example, the Search button in the upper middle right opened a search field at the lower center of the interface. Participants did not immediately see where their action had effect. We speculated that this problem would be heightened when in a store environment using a PDA.

- The iconography we used did not convey the intended meanings to participants. We decided that the icons should be replaced with text for clarity. We discovered that designing icons for a handheld display is even more complex than a desktop application because of the low resolution. One icon, an exclamation point, was placed on aisles where items from the list were located. At one point during the evaluation, several exclamation points were on the screen and a participant said this made him feel anxious and overwhelmed –almost stressed out from shopping. This was not our intention for the icon and we

again speculated that, in the store environment, the anxiety might even be exacerbated.

Our design iterations on the interface forced us to revisit the task analysis and reexamine the functions and features that shoppers said they wanted most. A robust prototype was developed for Microsoft Pocket PC Version 3.0.1[®] using Macromedia FLASH[®]. The handheld was a Compaq iPAQ[®] PDA with color display and stylus input. The interface, as shown in Figure 5, divided the display into three horizontal sections. The design rationale was that each section of the screen should have a specific function and location due to the complexity of interacting with a PDA while shopping.

The shopping list is centered across the screen because it is the most important element of the interface and the cohesive force to the physical task. Items in the list can be tapped once to strike through them as they are obtained. Icons next to the list items signify the item is on special. The user can tap the icon to view the specifics of the special in the promotional area.

Due to the generalizability of this application to a mass audience, we mapped the interface closely to the physical space of the store. The spatial map of the store appears above the list as a guide or navigation tool. It is used to encode location for search tasks because, in many cases, a user would describe their grocery shopping experience based on where they were located in the store.

Further, grocery bag icons were used to represent the location of grocery list items in the store. Tapping on a grocery bag filters the grocery list. As a result the grocery bag is highlighted and the items in the list that are located on that aisle change to red. In addition, the aisle numbers can be tapped to view a list of the aisle's contents.

The promotional area at the bottom displays revolving store specials based on the user's location in the store. Adjacent to the promotional area on the left are three buttons: Specials, Search and Home. By tapping the Specials button, the user can access a list of store specials that can be added to the shopping list. The Search button allows the user to type in an item to learn the aisle on which it is located. The Home button takes the user to the main screen where they can make or retrieve a shopping list or learn about the features of the application.

To increase a shopper's awareness of store promotionals we decided to use sound cues to alert the user of a special. For example, if the user's list displays apples and the user is in produce, a promotional will appear and a cue will sound from the PDA to alert them of the promotional specific to this situated interaction. These are referred to as reminders or situated reminders.

We believed this third iteration achieved a balance between the visibility of the grocery list, the interactions with the store map and the accessibility of the peripheral functions our participants had requested from the beginning. We

planned to test the situated interactions in a usability test within the shopping environment.



Figure 5. The final design used for usability testing

USABILITY TESTING IN THE ENVIRONMENT

Throughout our design process we felt that it was key that observations and evaluations be performed in the retail environment. One of the top priorities for our usability test was to simply establish whether people would find this tool useful while shopping. Additionally, we wanted to uncover how interacting with a PDA might affect the typical shopping experience.

We selected five individuals to participate in the in-store evaluation of the prototyped application on a PDA. The participants were in their 20s, 30s and 40s and three of the participants routinely make grocery lists. Due to our experience in the formative evaluation, the participants selected for the usability study were required to be familiar with the physical interactions involved when using a PDA. PDA interactions are different than PC interactions. We felt that users not familiar with using a PDA would inadvertently compromise their interactions with a PDA during testing.

We formulated a staged scenario that required the participants to shop from a pre-conceived grocery list and,

at the same time, utilize the features of the interface. Each participant was given a few moments to become familiar with the interface. They were given a brief description of the overall system and encouraged to ask questions regarding the interface.

We used a think aloud protocol in which the participants were asked to talk aloud while shopping and using the interface. Due to unfamiliarity of system functions or limitations of the prototype, verbal cueing was used when needed, to encourage trial-and-error exploration of interface features. Because none of the participants normally use a PDA while shopping, their cognitive resources were especially engaged in balancing grocery shopping and interacting with the PDA. For this reason, we attempted to limit our questions to a post-test interview.

The grocery store in which we conducted our pilot usability test requested that we not videotape. Therefore, we used audiotaping to capture the participants' comments during the staged scenario and post-test questionnaire/interview. The audiotapes were then transcribed for further analysis.

There were many challenges in performing the usability test in the store environment. Usability testing typically takes place on a desktop PC where actions performed on the interface can easily be monitored. However, when testing on a handheld, it becomes difficult to monitor what actions a participant is taking in the interface. This is important because we were interested in how the participant handled interruptions of the task. Were they appropriate for the situations? Specifically, an audio alert for an apple promotion was never heard. We did not take into account how loud the environmental noise would be in the store. As a result, participants' saw the promotion the next time they glanced at the PDA. A few times we had to ask participants if they noticed the promotional reminders because we could not see their actions.

In general, the participants said that the interface made shopping more efficient and easier to perform. A number of the participants commented on how quickly they shopped, how focused they were on the shopping list, and how they did not feel like they browsed while they shopped. One participant commented that normally he is "all over the store." He said that the interface helps him "move orderly through the store," and that, with the list on the application, he does not "even want to look around." He "just [wants] to go grab the item that is on the list." While this might not be good news for the grocery stores, quick and efficient shopping was stated as one of the most desired grocery shopping traits in the survey we conducted.

Interacting with a PDA while shopping directly affected the shopping experience. As we said earlier, participants noted that they tended to be more focused on obtaining the items on the list than allowing themselves to browse the store. Only one participant realized that she was standing at an end cap that displayed an item on her list. We repeatedly watched as the participants edited the grocery store environment down to the list on the PDA and locations of

the items. We speculate that initial use of this application could significantly lower impulse buys. However, once the learning curve is overcome, the grocery store space may be reopened and repetitive use may ensure adaptation.

A docking station for the PDA was a frequent request of the participants. They did not enjoy holding or carrying the device while shopping. A female participant would lay the PDA in her purse and then get it out when she needed it, similar to a physical list. Additionally, the backlight on the PDA went off for one participant, who was using a shopping basket. His hands were full of groceries so he had to place them on the floor to activate the screen again. In the post interview this participant further iterated that he does not like to carry a PDA and prefers smaller handhelds.

More specific to the interface, participants seemed to appreciate the interface's ability to identify the location of items in the store. Many of the participants relied strongly on the list filtering capability where, by tapping on a grocery bag icon in an aisle, items on their list were highlighted in red. They felt that this was a very useful feature and, once discovered, was probably the most utilized feature of the interface.

A feature that was less successful was the aisle look-up where a user taps on the aisle number to reveal contents of the specific aisle. During the usability test, a participant was asked to look up an item not on the list. After discovering that the aisle numbers offer help, she began to tap on each aisle number. Because the aisle listings were general descriptions, it was difficult for her to find the item. Eventually she became annoyed and stated that at this point she "would stop looking for the item in the interface and revert to using the [physical] store."

An interesting interaction involved striking items on the list. After participants had learned and even utilized the "tap to strike through an item" feature several times, when they wanted to find an item's location, they often tapped on the item for more information, thus mistakenly invoking the strike-through command. It became clear that the participants needed dual functionality when tapping on an item in the list.

There was a definite learning curve involved with this interface but once participants became familiar with its features, they generally felt that it added value to their shopping experience.

In the end, we believe that the participants found the tool useful and beneficial to their shopping experience. Even the non-list makers said they would be interested in using the tool if it were available. Since the usability test has ended, two participants have called to ask when the interface would be ready to download.

CONCLUSION

Throughout this paper we have discussed the intricacies of creating a mobile application that balances the act of shopping within the context of the shopping environment. Through our user-centered design process we have learned

many lessons in interface design, situated interactions and evaluation that are relevant to the design of a mobile application.

On Interface Design

As we speculated, a handheld application is appropriate for the on-the-go lookup activity of shopping. One lesson learned in designing for this activity is that visibility of the user's actions is most important. We found in evaluations that participants did not immediately see where their actions had an effect on the interface. Since a user is moving while interacting with the interface they must be able to quickly see what they are looking for and notice visual feedback. When designing, we accounted for this fact by placing the most needed functionality in a prominent position of the interface. We associated each section of the screen to a specific function due to the complexity of interacting with a PDA while shopping.

Strength of the Metaphor - Metaphors from the activity of shopping were used to further map the activity of shopping to the interface. This strength is evident when a user maps their actions to the interface and the interface to the situational context. A mobile interface that borrows directly from the physical setting strengthens the cognitive mapping for the user, e.g., aisles of the store, food categories, shopping basket, and grocery bags.

From user feedback we learned that objects in the interface require consistent feedback regardless of the number of their instances on screen. For example, the grocery bag and the text on the grocery list both represent a grocery item. The actions associated with the grocery item should result in the same consistent feedback. This was not evident until the final usability test where we discovered users associating these two representations with the same action.

On Situated Interactions

Situated interactions in the store, where the user utilizes the interface while shopping, became the greatest challenge for designing the interface. We learned from our users and task analysis that a design must account for distractions and the editing of the store. We identified appropriate times for interaction where a situated application could offer assistance to the user while shopping.

Navigation as an Aid - The spatial map of the store appears above the list and is used to encode location for search tasks because, in many cases, we heard users describing their shopping experience based on location in the store. The map serves as a navigation aid because a user looks at the interface to see what item is next on the list and then looks into the world for orientation. In this case the store map serves as a direct relationship to the environment to assist the user in finding products within the store.

Situated Reminders - Reminders should be relevant to the current situation and enhance on-the-go lookup activities. These serve as a complement to short-term memory. In the grocery store, users were provided with reminders for promotional items and products they wanted to purchase. To increase a shopper's awareness of a store promotion, we

decided to use sound cues to alert the user of a special. From this we learned that auditory cues can easily get lost in the environmental noise of a grocery store.

On Evaluations

The evaluations implemented as part of our design process were extremely valuable and revealed many lessons for mobile application design. Perhaps the most important lesson was that participants who are unfamiliar with how to use a PDA lack insight into interface functions that are not explicitly displayed and, therefore, inherently limit their actions on the interface.

Finally, there were many challenges in performing the usability test in the store environment. The testing was executed in a store environment to account for the context. In this case, videotaping was not an option. We found it very difficult to create a situated context to evaluate situated interactions. Equally as difficult was capturing a user's response within a situation since most of the editing was occurring in the head and not in the world. Unlike a typical usability test, which is performed at a stationary desktop PC, actions on the interface were not easily monitored.

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