USABILITY FOR MOBILE COMMERCE ACROSS MULTIPLE FORM FACTORS

Susy S. Chan
DePaul University, Chicago
schan@cti.depaul.edu

Xiaowen Fang
DePaul University, Chicago
xfang@cti.depaul.edu

Jack Brzezinski
DePaul University, Chicago
JBrzezinski@cti.depaul.edu

Yanzan Zhou
DePaul University, Chicago
yzhou@cti.depaul.edu

Shuang Xu
DePaul University, Chicago
shuangxu@yahoo.com

Jean Lam
DePaul University, Chicago
jeanlam@us.ibm.com

ABSTRACT

Current research on usability for mobile commerce has focused on single platforms and very limited aspects of commerce activities. We conducted an exploratory study to examine usability problems and to identify potential research questions concerning wireless solutions for consumer e-commerce. By using cognitive walkthrough and heuristic evaluation methods, we evaluated the usability of ten wireless sites in three platforms: WAP-enabled mobile phones, Palm OS based wireless PDAs, and Pocket PCs running Windows CE operating systems. This article discusses our usability findings pertaining to user tasks, content presentation, search, navigation systems, and the design constraints imposed by form factors. It also provides design guidelines based on our study and examines research implications for wireless interface design.

Keywords: usability, HCI, mobile commerce, e-commerce, wireless, handheld devices

1. Introduction

The current state of wireless technology poses many constraints for designing effective user interfaces for mobile commerce (m-commerce) applications. Small screen display, limited bandwidth, and the simplistic yet diverse functionality of wireless handheld devices affect usability. Insufficient attention to mobility in user tasks and data needs further hinders user adoption [Chan & Fang 2001]. Research to date has focused on very narrow tasks for m-commerce and only on the impact of single form factors. Users can access wireless sites through multiple platforms to perform both transactional and information retrieval tasks. An examination of the interactive effects of user tasks, form factors, and the purposes of applications on usability can benefit interface design for wireless applications. Given the early stage of m-commerce, such research should also consider the interaction between the wired and the wireless channels in order to determine how the wireless technology can be deployed to better support users' e-commerce activities.

During summer 2001, we conducted an exploratory study of usability issues for ten consumer wireless Web sites across three form factors – Palm OS based wireless PDAs (Personal Digital Assistant), Internet-enabled WAP (Wireless Application Protocol) phones, and Windows CE based Pocket PCs. Our objective was to assess the usability of wireless sites that represented the mobile solutions of some of the most popular consumer e-commerce sites. We focused on user tasks, content presentation, search, navigation systems, and the impact of form factors on usability. Another objective was to identify research questions and formulate design guidelines for wireless applications. This article provides a review of recent research, and presents our research methods, findings, design guidelines, and research implications.

2. Related Research

2.1 Defining Mobile Commerce

Researchers have adopted a broad definition of m-commerce to explore the potential benefits of the wireless technology. They view m-commerce as the use of wireless technology, particularly handheld mobile devices and mobile Internet, to facilitate transaction, information search and user task performance in consumer, business-to-business, and intra-enterprise communications [Chan & Fang 2001; Kannan, Chang, & Whinston 2001; Varshney & Vetter 2001]. M-commerce applications support not only transactions, but also value added services and interaction [Lehner & Watson 2001]. The wireless technology is particularly promising for enhancing relationships with customers [Kannan et al. 2001]. Despite the claim that m-commerce would revolutionize e-commerce, its wide adoption in business enterprises has not yet occurred due to technology limitations and unclear financial viability. Among all industry sectors, the retail industry is least certain about the future of mobile solutions [Ernst and Young,

2001]. Consumers have shown relatively low willingness to use m-commerce, but adopters of e-commerce are more likely to embrace m-commerce [Anckar & D'Incau 2002]. Given its latent adoption, one may consider the wireless channel as an extension of e-commerce that presents different requirements for interface design. The greatest challenge for various m-commerce applications is their usability. Even with the latest 3G phones in Japan, consumers still find usability barriers in small screen display and small buttons on these devices [Belson 2002].

2.2 Usability Research for E-commerce

Usability has received increasing attention for e-commerce due to the high cost of customer acquisition and retention for online retail sites. Usability research in this context tends to focus on site features that induce satisfactory online shopping. Formal usability studies have found that enjoyment in using the system and peer-group norms contributed to subjects' intention to use the system in the future [Henderson, Rickwood, & Roberts 1998]. Research has also found manipulation of visual design factors of the customer interface could induce a target emotion, such as trustworthiness [Kim & Moon 1998]. The use of a combination of navigation features (neighborhood, top, and index) to generate the optimal link structure could increase the degree of shopping pleasure and convenience [Kim & Yoo 2000]. These studies did not validate specific usability guidelines or address the broad range of user tasks.

Usability consultants have proposed guidelines for e-commerce Web site design pertaining to category pages, checkout and registration process, product pages and user trust [Nielsen, Farrell, Snyder, & Molich 2000a, 2000b, 2000c, 2000d]. Several unpublished research papers [Rehman 2000; Hurst & Gellady 2000; Hurst & Terry 2000] also examined customer experience and suggested design guidelines for home page, navigation, categorization, product information, shopping cart, checkout and registration, and customer service. These studies focused chiefly on the online shopping experience. Their recommendations are aimed at information-intensive transactional Web sites.

2.3 Usability Research for Mobile Commerce

Usability studies on wireless applications have centered on design constraints imposed by a bandwidth limitation and small display of handheld devices. Researchers found that directed access methods were more effective for retrieval tasks with small screen display [Jones, Marsden, Mohd-Nasir, Boone, & Buchanan 1999]. Novice WAP phone users showed better performance under two conditions: (1) when using links instead of the action screen for navigation among cards, and (2) when using lists of links instead of the selection screen for single-choice lists [Chittaro & Cin 2001]. Automatic conversion of HTML-based into WML (Wireless Markup Language)-based Web contents was feasible by following certain guidelines [Kaasinen, Anltonen, Kolarie, Melakoski, & Laakko 2000]. These studies did not test handheld devices based on appropriate m-commerce tasks, and they did not validate any framework or guidelines.

Many WAP usability problems resemble issues identified during the early stage of Web site development for PC computers [Ramsay & Nielsen 2000]. However, good user interface design can alleviate some of the usability problems for WAP phone users. Drawing from their experience in developing WAP access to an information system for tourists, Colafigi, Inverardi, and Matricciani [2001] recommended several design guidelines for WAP applications, including: (1) use short links, (2) include backward navigation on every card, (3) minimize the level of menu hierarchy, and (4) include headlines for each card. In their usability research of WAP phones, Buchanan, Farrant, Jones, Thimbleby, Marden, and Pazzaini [2001] identified similar design guidelines: (1) provide direct, simple access to focused valuable content, (2) use simple hierarchies, (3) reduce the amount of vertical scrolling, and (4) reduce the number of keystrokes. These studies focused solely on WAP phones. However, several studies were also undertaken on other platforms such as PDA and Pocket PC. Buyukkokten, Garcia-Molina, and Paepcke [2001] investigated various methods of text summarization for Web browsing on handheld devices and found that keyword/summary was the best method. Sugimoto [1999] studied single hand keys input schemes for pocket computers. Diverse form factors offer different functionalities and have different interface requirements. Studies that compare the usability issues for multiple platforms will help researchers and designers gain insights into content conversion and presentation for interface design in diverse contexts.

The context in which a user accesses the wireless sites also affects usability. Kim, Kim, Lee, Chae, and Choi [2002] identified three use context factors – hand, leg, and co-location – related to different usability problems. Problems of site structure were more likely to occur when participants used wireless sites with one hand instead of two hands. Those who accessed the wireless sites while moving rather than stopping experienced more difficulty with site representation. Those who were stopping or were alone reported more usability problems with content. Therefore, the design of wireless applications also needs to consider the use contexts.

3. Methodology

3.1 Usability Evaluation Methods

We used cognitive walkthrough and heuristic evaluation methods to evaluate the usability of wireless sites. In cognitive walkthrough, evaluators simulate novice users' walking through the interface to carry out predefined tasks, such as searching for and purchasing a book [Warton, Rieman, Lewis, & Polson 1994]. In heuristic evaluation, expert reviewers critique each site regarding user interface and overall design in order to determine its compliance with commonly accepted design rules [Nielsen 1994]. An advantage of using expert reviewers is that they usually can identify more usability problems. By using both methods, we were able to identify usability issues encountered by novice and experienced users while focusing on specific user tasks as well as design guidelines.

3.2 Form Factors

The three form factors examined in this study are: WAP-enabled phones, wireless PDAs using Palm OS, and Windows CE based Pocket PCs. They reflect the most popular underlying operating system and wireless Web browsing mechanisms in the North American market. WAP contents are written in WML to optimize data transmission. Among the numerous devices and wireless services available in the market, we selected AT&T Pocket Digital Net WAP phones and Sprint PCS WAP phones for this study, so that we could test the WAP access through two services and devices. Palm OS-enabled wireless PDAs can run Web clipping applications, which do not support several common Web page features: named type faces, style sheets, image maps, frames, nested tables, scripts, applets, and cookies. The two wireless PDAs we used were Palm VIIx and Handspring Visor Platinum. Pocket PCs run Microsoft's Windows CE operating system, which has a GUI similar to its desktop counterpart, but lacks many features and does not support some common Web page features such as frames. We chose HP Jornada 548 for the study, which runs Pocket PC OS, an upgraded version of Windows CE. In general, Pocket PCs have more memory and functions, a slightly larger screen, and a higher resolution than Palm OS devices do.

3.3 Site Selection

Three criteria guided our selection of wireless Web sites for this study: (1) high volume of traffic at their Internet Web sites, (2) capability of supporting WAP and Palm OS platforms, and (3) representing a broad range of consumer m-commerce activities as a set. Site traffic was determined by the number of unique visitors, published monthly by Jupiter-Mediametrix (www.mediametrix.com), an Internet media research firm. By using the broad definition of m-commerce, we started with a large set of high traffic Web sites in five sectors – travel, retail, financial services, news, and portals. These sectors offer time-sensitive services for users of mobile devices, such as checking flight schedules and stock quotes. We then searched their Internet Web sites to determine their core services and whether they offer wireless solutions for WAP phones and Palm OS. Few Internet Web sites offered mobile solutions for Pocket PCs. Therefore, we accessed the selected sites on Pocket PCs by keying in regular URLs. These steps enabled us to narrow down the selection to ten wireless sites for this study: travel (Travelocity and United Air Lines), retail (Amazon and eBay), portal (Yahoo and Excite), financial services (Fidelity and E*Trade), and news (ABC News and the Wall Street Journal). This set included both Internet pure-plays and traditional services that extended to Internet. Together, they represented a wide range of m-commerce tasks and interfaces for review.

3.4 Procedure

We conducted the research over three months during the summer of 2001. Two graduate students participated as novice users and conducted cognitive walkthroughs of predefined tasks by accessing all ten sites with three types of devices. Four experienced evaluators performed heuristic evaluations of all ten wireless sites using three handheld devices. In this study, novice users were defined as users who were naïve in the human-computer interaction field and did not have experience using any handheld devices to access wireless sites. Expert evaluators were professionals who had extensive working experiences and knowledge in the human-computer interaction field. However, these expert evaluators were not experts at using handheld devices.

User tasks for the cognitive walkthrough included: checking flight schedules and booking a flight (for travel sites), searching and buying a book (for Amazon), searching and bidding on an item (for eBay), searching a movie (for portal sites), checking stock quotes (for financial sites), and searching top news (for news sites). For heuristic evaluations, expert evaluators examined not only these tasks but also explored other features at these sites following usability guidelines. Because of the delay in setting up WAP services, we conducted the evaluation sessions on wireless PDAs and Pocket PCs first. All sites were reviewed category by category using both PDAs and Pocket PCs for the same sites. Reviews for WAP access were conducted afterwards. Reviewers carried out these sessions on the bus, on the train, at home, and in the office. Because of the unsteady connection when accessing these services in moving vehicles, we had to adjust the research plan to allow data collection in both stationary and mobile environments. A similar experience was reported in a WAP usability study [Ramsay & Nielsen 2000]. Each reviewer conducted all the sessions individually and documented his or her observations in written reports in a

consistent format. Whenever a reviewer identified a usability problem, a brief description of the problem along with the context, underlining usability guideline, and screenshot(s) were recorded. The research team met weekly to compare observations and summarize findings.

4. FINDINGS

4.1 User Tasks

In a mobile environment, users have limited time and cognitive resources to spare for performing tasks. One of the key design issues for wireless applications is what tasks are suitable. Table 1 presents some of the tasks supported by the current wireless Web sites and performed in this study. Two types of tasks were identified: transactional tasks and information retrieval tasks. A transactional task refers to any task that requires changes to be made in databases, while an information retrieval task involves only information searching and browsing. A complex task can start as an information retrieval task, which is then carried out as a transactional task. Some tasks are carried out in two steps between the wireless and the wired channels. For example, a new customer for mobile eBay needs to register first, and then go to the computer for email confirmation before submitting the bid on the wireless device.

Table 1: User Tasks by Sites

Category of Tasks	Wireless Site / Task		
	Category of Web sites	Wireless Site	Task
Transactional Tasks	Travel	Travelocity	Booking a flight
		United Air Lines	Booking a flight
	Retail	Amazon	Buying a book
		eBay	Bidding on an item
Information Retrieval Tasks	Portal	Yahoo	Searching a movie
		Excite	Searching a movie
	Financial	Fidelity	Checking stock quotes
		E*Trade	Checking stock quotes
	Travel	Travelocity	Checking flight schedules
		United Air Lines	Checking flight schedules
	Retail	Amazon	Searching a book
		eBay	Searching an item
	News	ABC News	Searching top news
		The Wall Street Journal	Searching top news

We found that tasks in all sites accessed using mobile devices were designed with steps similar to their counterparts designed for PC-based access. Some sites only included narrowly defined tasks for wireless access, particularly for travel, financial, and news. Retail sites, such as Amazon and eBay, tended to provide text-rich contents identical to the Internet Web sites, such as book reviews, even for a much smaller set of tasks on the wireless sites.

Wireless application developers are challenged to design interfaces that accommodate both expert and novice users. On a typical screen of a wireless site (Figure 1), little instruction was provided about how to perform the task, partly due to the limited space on the screen. Since users are supposed to follow similar steps to perform a task on wireless sites as they would on regular sites, lack of instruction should not pose any problem to experienced users of the regular sites. This design strategy allows existing customers to transfer knowledge about a Web site to the wireless site. However, novice users who have never browsed the sites using a PC may find it very difficult to accomplish a task using a mobile device.

Figure 1. A wireless site with little instruction

Many transactional tasks, such as bid submission for eBay and "Buy Now with One Click" for Amazon, assumed user's prior experience with the interface on the regular Web sites. Therefore, little instruction was provided for novice users. Many sites, such as Travelocity, required registration on regular Web sites before permitting users to access some of the features on the wireless sites. However, few wireless sites provided clear exits, particularly for sites with deep menu structure. This was observed for all three form factors. Many sites also designed interfaces to attract repeat users. For example, both Fidelity and E*Trade allow users to customize a watch list of stocks for the Palm applications. Editing this list often required numerous trials.

4.2 Content Presentation

Currently mobile computing is still facing the problem of limited bandwidth. It is not feasible to exchange a large amount of information between a handheld device and the base station. Although we found almost all wireless sites had already removed much information from their regular sites, often the information was still excessive for a small screen. We observed the following problems caused by limited bandwidth.

Long Downloads and Broken Connection. Limited bandwidth prevented a fast download of a large amount of information. Furthermore, wireless service is not always reliable. The likelihood a lengthy Web page interrupted by a broken connection increased dramatically. This problem occurred most frequently on Pocket PCs. Currently, most Internet Web sites do not have a wireless version for Pocket PCs. Consequently more information must be downloaded to the Pocket PC devices as compared to other devices such as Palm handhelds. In our study, we observed an average of more than 20 minutes to download a typical Web page without large-size images, with more than 50% of the processes being interrupted by broken connections. This problem might be caused partly by the wireless service. We also experienced problems with transactional tasks and extensive information searches with the Palm handhelds. Some transactional tasks, which involved data exchange in multiple screens (such as account summary), often failed to connect or were disconnected half way through. Lengthy pages, such as uncondensed book review pages on the wireless Amazon sites, could take a long time to download and no exit was provided.

Vertical and Horizontal Scrolling. A lengthy Web page might require vertical or horizontal scrolling. While vertical scrolling is not preferred [Buchanan et al. 2001], horizontal scrolling can directly cause failures of functions of a site. In the example presented in Figure 2, users were supposed to enter a string in the text box and hit an action button. However, due to required horizontal scrolling, users could not see the action button after entering the string. Novice users, not knowing what to do, might quit the task. We found scrolling problems for contents designed for WAP phones and wireless Palm to be less severe.

Figure 2. A Web page requiring both horizontal and vertical scrolling

Information Overload. Inappropriate design can cause information overloading. Figure 3 shows a typical sequence of steps in booking a flight or checking flight schedules on a wireless Web site. Users are required to enter the airport code rather than the airport name. Those unable to remember the magic 3-character airport code have to access another page to look for the code, remember it or write it down in a piece of paper before returning to the current page and to enter the code. Clearly the system places too many demands on the user's memory.

Figure 3. Steps to find an airport code

Depth of Site Structure. Mobile users, away from a stationary computer or in a mobile environment, are likely to have limited time to access and browse a wireless application. Good organization of information is critical for achieving greater efficiency. Information in most wireless applications is typically organized as a hierarchical structure, and requires much more time and effort to connect to the server and download a page. Consequently, a flatter structure with fewer steps would allow users to review more options in the same step and to locate the desired information in less time. Figure 4 presents a flat hierarchical structure that had received positive feedback from the reviewers. This result is consistent with findings of several studies on WAP usability: direct links and lists of links are more effective than action screens and selection screens for single-choice lists [Chittaro & Cin 2001], and simple hierarchies reduce scrolls [Buchannan et al. 2001]. We had a similar experience with the wireless Palm.

Figure 4. Steps to find a book by browsing

Search. Two types of searches are provided at these wireless sites: by predefined codes (such as an airport code) and by keywords (such as a book title). Searching by code for airports, stocks and movie theaters can be done rather efficiently as long as the user memorizes the code. Searching by keyword can yield mixed results. Amazon always returns three results of recommended books and lists the rest alphabetically in a group of six titles. One can use additional keywords to narrow down the search. A keyword search on eBay's wireless site can yield numerous returns. It was difficult for users to see all the results and the list could be too long to download. Predefined options for search can simplify the user's decision process. However, we found these options were either absent or not clearly marked.

4.3 Navigation Systems of Handheld Devices

On the assumption that most users of wireless applications have browsed Internet Web sites, the best navigation system on a wireless handheld device would be a system similar to those on the Web. However, we noticed that navigation systems on handheld devices were different from those of PC-based Web applications, and were inconsistent across different form factors. Figure 5 illustrates navigation systems of the following handheld devices: a wireless Palm, a Pocket PC, and a WAP phone.

- The Palm handheld device provides a few buttons that can be used to access some built-in applications such as Address, Memo, and Calendar. For Web browsing, there are two clickable tabs on the top of the screen: one serving as the "Back" function and another displaying a history list. The history list is presented in a different way compared to the history list on a regular browser. Because the "Back" tab is almost identical to the "Back" button, although the device does not look like a regular browser, the interface should not cause users much confusion.
- The Pocket PC also provides a few buttons to access some built-in applications. However, this device has a mini-Internet Explorer (IE) browser that provides Web browsing function. The mini IE browser has a similar look as the regular IE browser, but the layout is different. The similar look might lead most users who are familiar with IE to expect that buttons with various functions will be presented in similar locations as regular IE. As illustrated in Figure 2, the navigation tool bar is located at the bottom of the screen and it includes fewer buttons. There is no direct button to access the history list. Usability problems may arise because of users' expectation and the inconsistent navigation system.
- The WAP phone usually includes four keys that can be used for Web browsing. Two of them provide scrolling functions and the other two provide functions similar to "Back" and "Forward." However, when navigational hyperlinks are presented to move to another page in some wireless Web sites, the same two keys will be used to select the hyperlinks and serve for totally different functions. The shift of functions of the same keys can cause user disorientation.

Figure 5. The navigation system of a Palm handheld, a Pocket PC, and a WAP phone

4.4 Connection Feedback and Latency

We also found that some handheld devices failed to give users prompt and informative feedback. The most problematic device was the Pocket PC. It failed to provide instant and proper feedback in the following two cases: (1) The Pocket PC did not display signal strength on every screen, which is crucial for users on the move to make a successful connection. Most of our reviewers had tried to connect to a site without knowing that the signal strength was too low to make a connection and even worse, they usually received a false error message indicating that the server was down. (2) During the download process of a Web page, there was no clear indication of the progress. Because the bandwidth was limited, it took a relatively long period to download a Web page. Without any indication of the download progress, users might not be able to feel in control and might consequently abort the task.

4.5 Platform Specific Issues

We found form factors to play important roles in the interface design of wireless applications because they are accessible through multiple platforms. These platforms use different operating systems and offer different functionalities. Platform specific issues would impact interface design. Figure 6 illustrates two such issues on a wireless Palm handheld. A typical drop-down box appears with no boundary on a Palm handheld. When the two items "State" and "Select State" are close enough, it is difficult to associate the drop-down box with one of them. Figure 6 also displays the password fields on a Palm handheld. Since the term "Unassigned" always appears in a password field by default, it could be viewed as the default password instead of a blank field.

5. Recommended Guidelines

Based on the above findings, we recommend eight design guidelines for wireless applications. The included guidelines are pertinent to all form factors that have been analyzed. Some of the design guidelines apply to and can be used in designing interfaces for PC-based Web applications. One might find out that, in general, interface design flaws are platform independent. However, the more limitations imposed on the form factors (e.g., small screen), the more acute the design problems become.

1) *Avoid scrolling, especially horizontal scrolling.*
   Scrolling, especially horizontal scrolling, can severely hinder a user's browsing behavior. It is better to limit the page length and format the page to fit the screen width in order to avoid scrolling. If it is difficult to reduce the amount of search results, information should be grouped into categories.
2) *Use a flat hierarchy.*
   Since every step takes longer on handheld devices, a flat hierarchical structure with fewer steps is preferred.
3) *Design a navigation system consistent with a regular Web browser.*

This consistency enables users who have been using regular Web browsers to transfer their browsing knowledge to mobile applications. The design of handheld devices and browsers running on them must adopt similar metaphors and layout should resemble regular Web browsers. The navigation aids should be specific for mobile devices.

4) Design a "Back" button with the same function as it has in a regular browser.
Previous studies indicated that "Back" is the most frequently used function in Web browsing. It is better to implement in wireless applications a "Back" function that is the same as its counterpart on a regular browser.

5) Provide a history list that records the order in which hyperlinks have been traversed.
The history list should present previously visited Web sites as a stack.

6) Provide indication of signal strength and downloading progress on every screen.
Signal strength indicator helps users determine the tasks to be performed on the move. Downloading progress help users determine the speed of data transmission.

7) Do not require users to remember items.
Provide appropriate navigation to bring users back to the data entry page after reviewing the codes, or provide a help screen without leaving the data entry screen.

8) Limit the search scope to improve search efficiency.
Improve the search precision by intelligent query support and predefined search options. The predefined search options should simplify the formulation of user information needs and speed up or even skip the form input process.

Figure 6. Device specific issues of wireless Palm handhelds

6. Research Implications

6.1 Development Methods

Our study suggests that developers of interfaces for wireless applications should devote more attention to the context of users' behaviors and tasks during the requirement gathering phase. Traditional means of user interviews or usability testing in a laboratory environment assumes a *fixed* context of use. Mobile computing alters this assumption. In order to reveal insights of users' activities and mobility in their real life, requirement analysis should give greater attention to user contexts [Johnson 1998]. Some researchers have advocated the use of contextual inquiry (CI) to augment user interface design by exploring the versatility of usage patterns and usage context [Väänänen-Vainio-Mattila & Ruuska 1998]. Others have suggested use contexts could affect usability in accessing the mobile Internet [Kim, et al. 2002].

Usability testing should also be performed in mobile contexts. We experienced difficulty in accessing some mobile services due to latency and unsteady connection. However, by conducting evaluation sessions in both stationary and mobile environments, we gained insights into the complexity of contextual variations that may affect the usability of wireless applications.

Contextual variations exist in infrastructure, applications, and location. These variations result from interactions between the mobile devices used and the supporting wireless infrastructure, between the mobile devices

and the goals and tasks performed by the user, and among the architecture for content distribution, devices, and infrastructure [Rodden, Chervest, & Davies 1998]. It is challenging but necessary to design interfaces to function in a broad range of applications for consumer m-commerce sites. But for enterprise uses in a more predictable environment and pre-specified workflow, it may be easier to anticipate these variations for interface design. Further research is needed to identify appropriate testing and design methods.

Furthermore, in the current environment of multiple standards and platforms, it is essential to map applications according to unique features or constraints of form factors in order to ensure effective content presentation and interface design. For example, United Air Lines mapped its wireless applications across one-way pagers, WAP phones, and wireless PDAs according to the timing and the degree of involvement in user tasks and the characteristics of form factors [United Air Lines, Inc. 2001]. Users can perform non-transactional tasks, such as checking flight status, by using both wireless PDAs and WAP phones. However, transactional tasks that involve a lot of data exchange and user interactions, such as Mileage Plus Upgrade Status and Mileage Plus Award Travel Availability, are accessible only through wireless PDAs. For tasks that require more time for decision-making and extensive information exchange (such as trip planning), desktop computers are the most appropriate platform. This deliberate mapping approach is essential for managing interface design and content conversion.

6.2 Content Conversion

Content conversion between wired and wireless channels and across multiple platforms is an important research topic. Research in this area [e.g., Kaasinen et al. 2000] has not addressed usability issues. Currently a large part of online content is developed in an unstructured way, e.g., HTML, for Internet Web site presentation. It can make content editing for wireless devices very labor-intensive. To automate cross-platform conversion of content, XML-based content representation can introduce structure into the content and treat on-screen formatting separately. As a result, the same content represented in XML can be easily customized and displayed on mobile devices as well as on desktop PCs. Migration into XML-based content representation is already under way. How to incorporate interface design in such development deserves further research.

Conversion of the navigational structure may also affect usability for wireless access. The browsing strategies using client-side log files [Catledge & Pitkow 1995], may not be suitable for mobile devices due to the interface usability issues. For example, designing the hyperlinks for a WAP phone screen is quite a different task from the navigational design for a Pocket PC. Undoubtedly the number of hyperlinks displayed within a single screen or page will have to be smaller than the number of hyperlinks displayed on a desktop PC. On-line content is usually categorized through menus of hyperlinks. The resulting structure is an ontology with the most general (navigational) documents at the top of the structure and the specific content at the bottom. So far there is no research into the problem of the summarization of information represented in hierarchies.

The aesthetic effects on usability [Schenkman & Joensson 2000] are often absent in displays on such platforms as Palm OS or WAP phones. All the powerful client-side scripting technologies such as Cascading Style Sheets or JavaScript are not available. The problem of representing the graphic design of a regular Web site on a mobile device requires a conversion of major elements of graphics design: text, multimedia content, and layout. In terms of images, the conversion may not be possible because most mobile devices (except pocket PCs) have very limited capability for displaying graphics. The implication is that in order to be able to convey information represented by the non-textual media as text, one needs to annotate this content.

Furthermore, conversion of search tasks is of critical importance. In general one can categorize searching into two groups of tasks. The first group of tasks relates to the retrieval of information from structured databases, such as searching for flight availability. The second group of tasks relates to the retrieval of natural language-based information. Many search engines are capable of retrieving relevant information. However, all of them are sensitive to the accuracy of user queries. Entering text data is difficult on most wireless handheld devices. Simplified search interfaces using direct links and link lists are useful for WAP phone users. Our study found that similar search strategies also worked for wireless Palms. More research is needed to investigate task conversion from Internet Web sites to the wireless sites supporting simplified search interfaces.

6.3 Coordination of M- and E-Commerce

Research has indicated a strong relationship between e-commerce and m-commerce [Anckar & D'Incau 2002]. Adopters of e-commerce are most ready to embrace mobile services that add values to e-commerce. This close relationship suggests that it is important to coordinate user tasks and interfaces presented by e-commerce and m-commerce sites. Although the wireless sites currently offer very limited content and services, those available on the wireless sites tend to share similar interfaces with their regular Web sites. Many sites were designed especially for existing customers or subscribers familiar with a site's unique interfaces. For example, Amazon Anywhere (the wireless site for Amazon) offers only the one-click ordering feature for wireless purchases. Though it is an efficient feature for those who have already established trust with the regular Amazon site, it does not allow novice users to

back out of the purchase easily. When connection is broken, a customer's data for registration or a one-click purchase may get lost in transmission without any warning or feedback. So, while the synchronization of interfaces between two channels provides a fast shopping experience for users experienced with wireless handheld devices, it requires a high degree of user trust regarding brand and transaction security. Research is needed to understand how user trust and perception of security in the wireless environment relate to usability, and to what extent user trust may be transferable from prior experience with the e-commerce sites to a wireless site.

Contrary to the argument for automatic content conversion, one may advocate that the interface for wireless sites should follow different design guidelines to cope with constraints imposed by wireless platforms and use contexts, as discussed in Chittaro and Cin [2001], Buchanan et al. [2001], and Kim et al. [2002]. In this case, the mapping of user tasks between m- and e-commerce is important. For the same task, it may be necessary to simplify the wireless interface to ensure the essential content and workflow are preserved so users can perform the tasks without new learning. The two channels may support different tasks or different steps of a complex task. For example, users have to register on line before using the user ID for wireless purchase, or initiate a bid on an auction Web site and monitor the progress on the wireless site. In these cases, the wireless interface should be as simple as possible and does not necessarily follow the online version. How to segment a complex user task or a complete experience into concrete steps for distribution between the two channels is worth of a closer look.

The wireless technology offers unique promise for strengthening relationships with customers because of its ability to personalize content and services, and to track the user across media and over time [Kannan et al. 2001]. Our research has shown that repeat and novice users may expect different interface design and contents. Ways to customize the Web content, search strategies, choices of user tasks, and wireless services should be considered to improve usability of the wireless applications. This may be the ultimate approach for building loyalty through the wireless channel. Research in this area will bring new understanding about how customization can improve usability.

7. Conclusions

This exploratory study has enabled us to identify many issues surrounding the current implementation of wireless solutions for mobile consumers. All these solutions were designed primarily to support existing customers or subscribers. Through the wireless channel, these users can continue accessing a small set of Internet services and content available at the regular sites. New wireless users need to register with the regular sites in order to access all the features. This means that the wireless sites are aimed at strengthening customer relationships and loyalty. For these users to take advantage of the wireless channel, usability of these wireless sites needs to be significantly improved. We identified the need to provide interface support for both novice and experienced users at these sites. The content should be displayed in shorter length, require little scrolling and user memory, use flat site structure and a navigation system similar to the regular browser with consistent back and history, and provide indications for signal strength and download progress. Among the three form factors studied, we found the Pocket PC to be the least satisfactory device for accessing wireless sites, because the browser has yet to display content designed for the desktop computer. Wireless PDAs can be useful for clearly defined tasks and content display.

Due to the nature of cognitive walkthrough and heuristic evaluation methods, the findings in this study were derived from the subjective observations of the evaluators and they might not reflect all the usability problems with wireless Web sites. We urge researchers and developers to consider the contextual variations present in the mobile environment when conducting requirement analysis and usability testing. Greater attention should be devoted to understanding user tasks in mobile environments, particularly the relationship between the Internet and the wireless channel. Such research will gain new insights about how a complex task should be mapped across distributed channels and multiple form factors. Content conversion faces many challenges concerning usability, providing opportunities for research on technical solutions and information modeling. Finally, the usability issue is critical to the adoption of m-commerce. Although our research is focused on consumer sites, the research implications and technical solutions may have greater relevance to m-commerce for intra-enterprise and CRM purposes, when user tasks, content presentation, and form factors are carefully mapped.

REFERENCES

Anckar, B. and D. D'Incau, "Value-Added Services in Mobile Commerce: An Analytical Framework and Empirical Findings from a National Consumer Survey," Proceedings of the 35th Annual Hawaii International Conference on System Sciences, Los Alamitos, CA: IEEE Computer Society Press, 2002.

Belson, K., "Japan Is Slow to Accept the Latest Phones," *The New York Times*, April 22, 2002, p. C4.

Buchanan, G., S. Farrant, M. Jones, H. Thimbleby, G. Marsden, and M. Pazzani, "Improving Mobile Internet Usability," Proceedings of the Tenth International World Wide Web Conference, New York, NY: ACM, 2001.

Buyukkokten, O., H. Garcia-Molina, and A. Paepcke, "Seeing the Whole in Parts: Text Summarization for Web Browsing on Handheld Devices," Proceedings of the Tenth International World Wide Web Conference, New York, NY: ACM, 2001.

Catledge, L. and J. Pitkow, "Characterizing Browsing Strategies in the World Wide Web," *Computer Networks & ISDN Systems*, Vol. 27, No. 6:1065-1073, 1995.

Chan, S. and X. Fang, "User Interface for Mobile Commerce," Unpublished manuscript, 2001.

Chittaro, L. and P. D. Cin, "Evaluating Interface Design Choices on WAP Phones: Single-Choice List Selection and Navigation Among Cards," In M.D. Dunlop and & S.A. Brewster (eds.), Proceedings of Mobile HCI 2001: Third International Workshop on Human Computer Interaction with Mobile Devices, 2001.

Colafigli, C., P. Inverard, and R. Martriccian, "InfoParco: An Experience in Designing an Information System Accessible through WEB and WAP Interfaces," Proceedings of the 34th Hawaii International Conference on System Science, Los Alamitos, CA, IEEE Computer Society Press, 2001.

Ernst & Young, "Global Online Retailing: An Ernst & Young Special Report," Cap Gemini Ernst & Young, January 2001. Available online: http://www.ey.com/global/vault.nsf/US/2001_Retail_Study/$file/GOR.pdf

Henderson, R., D. Rickwood, and P. Roberts, "Beta Test of An Electronic Supermarket," *Interacting with Computers*, Vol. 10:385-399, 1998.

Hodkinson, C., G. Kiel, and J. Mccoll-Kennedy, "Consumer Web Search Behaviour: Diagrammatic Illustration of Wayfinding on the Web," *International Journal of Human Computer Studies*, Vol. 52: 805-830, 2000.

Hurst, M. and E. Gellady, "White Paper One: Building a Customer Experience to Develop Brand, Increase Loyalty and Grow Revenues," unpublished report, 2000.

Hurst, M. and P. Terry, "The Dotcom Survival Guide," Unpublished report, 2000.

Jacko, J. A., Salvendy, G., and R.J. Koubek, "Modeling of Menu Design in Computerized Work," *Interacting with Computers*, Vol. 7, No. 3: 304–330, 1995.

Jacko, J. A. and G. Salvendy, "Hierarchical Menu Design: Breadth, Depth and Task Complexity," *Perceptual & Motor Skills*, Vol. 82, No. 3: 1187–1201, 1996.

Johnson, P., "Usability and Mobility: Interactions on the Move," in C. Johnson (Ed.), Proceedings of the First Workshop on Human Computer Interaction with Mobile Devices, 1998.

Jones, M., G. Marsden, N. Mohd-Nasir, K. Boone, and G. Buchanan, "Improving Web Interaction on Small Displays," *Computer Networks: the International Journal of Distributed Informatique*, Vol. 31:1129-1137, 1999.

Kaasinen, E., M. Aaltonen, J. Kolari, S. Melakoski, and T. Laakko, "Two Approaches to Bringing Internet services to WAP Devices," *Computer Networks: the International Journal of Distributed Informatique*, Vol. 33: 231-246, 2000.

Kannan, P., A. Chang, and A. Whinston, "Wireless Commerce: Marketing Issues and Possibilities," Proceedings of the 34th Hawaii International Conference on System Sciences, Los Alamitos, CA: IEEE Computer Society Press, 2001.

Kim, K., J. Kim, J., Y. Lee, M. Chae, M., and Y. Choi, "An Empirical Study of the Use Contexts and Usability Problems in Mobile Internet," Proceedings of the 35th Annual Hawaii International Conference on System Sciences, Los Alamitos, CA: IEEE Computer Society Press, 2002.

Kim, J., and J. Moon, "Designing Towards Emotional Usability in Customer Interfaces - Trustworthiness of Cyber-Banking System Interfaces," *Interacting with Computers*, Vol. 10:1-29, 2000.

Kim, J., and B. Yoo, "Toward the Optimal Link Structure of the Cyber Shopping Mall," *International Journal of Human-Computer Studies*, Vol. 52:531-551, 2000.

Lehner, F. and R. Watson, "From e-Commerce to m-Commerce: Research Directions," University of Regensburg, 2001. Available online: http://www-mobile.uni-regensburg.de/(en)/freiedokumente/Berichte/ResearchDirections.pdf

Miles, G., A. Howes, and A. Davies, "A Framework for Understanding Human Factors in Web-Based Electronic Commerce," International Journal of Human Computer Studies, Vol. 52:131-163, 2000.

Nielsen, J, "Heuristic evaluation," in J. Nielsen and R. Mack, (eds.), Usability Inspection Methods. John Wiley & Sons, New York: NY, pp. 25-62, 1994.

Nielsen, J., Designing Web Usability: the Practice of Simplicity, New Riders, Indianapolis, Indiana, 2000.

Nielsen, J., "What Is Usability?" 2001. Available onlin: http://www.zdnet.com/devhead/stories/articles/0,4413,2137671,00.html

Nielsen, J., S. Farrell, C. Snyder, and R. Molich, "R. E-commerce User Experience: Category Pages," unpublished report, Nielsen Norman Group, 2000(a).

Nielsen, J., S. Farrell, C. Snyder, and R. Molich, "E-Commerce User Experience: Checkout & Registration,"

Unpublished report, Nielsen Norman Group, 2000(b).
Nielsen, J., S. Farrell, C. Snyder, and R. Molich, "E-Commerce User Experience: Product Pages," Unpublished report, Nielsen Norman Group, 2000(c).
Nielsen, J., S. Farrell, C. Snyder, and R. Molich, "E-Commerce user experience: Trust. Unpublished report. Nielsen Norman Group, 2000(d).
Ramsay, M., and J. Nielsen, "WAP Usability: Déjà Vu: 1994 All Over Again," Unpublished report, Nielsen Norman Group, 2000.
Rehman, A., "Holiday 2000 E-Commerce," Unpublished report, Creative Good, New York, NY, 2000.
Rodden, T., K. Chervest, and N. Davies, "Exploiting Context in HCI Design for Mobile Systems," in C. Johnson (Ed.), Proceedings of the First Workshop on Human Computer Interaction with Mobile Devices, 1998.
Ruuska-Kalliokulju, S., M. Schneider-Hufschmidt, K. Väänänen-Vainio-Mattila, and B. Von Niman, "Shaping the Future of Mobile Devices: Results of the CHI2000 Workshop on Future Mobile Device User Interfaces," in M.D. Dunlop and S.A. Brewster (eds.), Proceedings of Mobile HCI 2001: Third International Workshop on Human Computer Interaction with Mobile Devices, 2001.
Schenkman, B., and F. Joensson, "Aesthetics and Preferences of Web Pages," *Behaviour & Information Technology*, Vol. 19, No. 5:367-377, 2000.
Sugimoto, M., "Application of Single Hand Keys Input Scheme to Pocket Computer," *Fujitus Sci. Tech. Journal*, Vol. 35, No. 2:181-190, 1999.
United Air Lines, Inc. "United EasyAccess," 2001. Available online: http://www.ual.com/site/primary/0,10017,1972,00.html
Väänänen-Vainio-Mattila, K. and S. Ruuska, "User Needs for Mobile Communication Devices: Requirements Gathering and Analysis through Contextual Inquiry," in C. Johnson (Ed.), Proceedings of the First Workshop on Human Computer Interaction with Mobile Devices, 1998.
Varshney, U. and R. Vetter, "A Framework for the Emerging Mobile Commerce Applications," Proceedings of the 34th Hawaii International Conference on System Sciences, Los Alamitos, CA: IEEE Comp Society Press, 2001.
Wharton, C., J. Rieman, C. Lewis, and P. Polson, "The Cognitive Walkthrough Method: A Practitioner's Guide," in J. Nielsen and R. Mack, (eds.), Usability Inspection Methods. John Wiley & Sons, New York: NY, pp. 105-140, 1994.
Zhang, P., G. von Dran, G., R. Small, and S. Barcellos, "Websites that Satisfy Users: a Theoretical Framework for Web User Interface Design and Evaluation," Proceedings of the 32nd Hawaii International Conference on System Science, pp. 69-76, Los Alamitos, CA: IEEE Computer Society Press, 1999.