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Scrolling Versus Menus on Small Mobile Device Screens: A Mobile Portal Usability Study

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Abstract

Developing an application interface for wireless portable devices that is acceptable to end-users is more complex than it is for desktop displays. One way this challenge can be addressed is by providing application access through wireless Web portals. This paper presents a usability study of a wireless Web application, based on reusable portlets that support different functionalities through wireless PDAs. Two wireless PDA (Personal Digital Assistant) interfaces were developed for an organizational application. The first used a PDA display of the equivalent desktop version that made all functionalities available by scrolling, and the second version utilized five portlets in separate displays, each supporting a functionality that linked to the other portlets through menus. Summative comparisons of the wireless interfaces were used to gather user perceptions of three versions of the interface: a full desktop computer display, the scrollable PDA version, and the menu-driven PDA version. Outcomes indicated that users preferred the desktop interface but their ranking was indifferent between the menu-driven and scrollable PDA interfaces.

1 Introduction

There is a rapidly growing population of more than 2.6 billion wireless mobile subscribers worldwide, including more than 600 million mobile office users (Wailgum, 2007), with at least 100 million mobile data services users in this population (D'Anci, 2004). Much of the recent growth of data services (estimated at 30% per year (Sacco, 2007)) has been through smartphones (devices such as the *Blackberry* that use an identifiable operating system, with the ability to add applications). With the rate of advance of wireless networking technology and mobile devices, combined with linkages to the Internet, users can now access information system virtually anytime, anywhere, via various handheld devices such as mobile wireless phones, PDAs (personal digital assistants), tablet PCs, and smartphones.

Mobile applications (software systems operating on mobile devices (Zhang & Adipat, 2005)), are evolving rapidly along with the rapid growth of mobile subscribers, making ubiquitous information and application access a true reality. Mobile phone applications in particular are beginning to enter environments that were historically reserved for PDA applications, so the distinction between these two classes of mobile devices is beginning to blur and may eventually disappear. With its rich connectivity to personal and wide area networks (PANs/WANs), the mobile phone is a gateway device and service platform that is becoming a pervasive applications platform (Marples & Moyer, 2004). Although the availability and use of wireless connectivity is steadily increasing, the question of usability of handheld devices has been problematic. All handheld wireless devices tend to have limitations in terms of power, memory, resolution, and screen size. The ergonomics challenges of these devices involve tradeoffs between increasing levels of miniaturization and the relative size of the human hand and the visual acuity of the human eye (Pagani, 2007). This causes problems when attempting to display Web content more suitable for full-sized computer screens. Ignoring these differences is a recipe for failure.

The history of information technology has recorded many technically good system designs that were rejected in practice because they did not adequately cater to users' subjective as well as objective needs, desires, and limitations. These problems have often been caused by a lack of attention to usability design during information system development. This typically leads to a lack of user acceptance of systems, failure to support work practices, introduction of errors, and inadvertent changes in workflow (Kushniruk, 2002; Kushniruk & Patel, 1998).

The research reported in this paper is directed towards the usability of organizational applications of wireless mobile systems. First, a brief literature review discusses wireless usability methodologies, handheld devices, and concepts of wireless portals. Second, the construction of a prototype wireless portal is discussed, that supports two different interface designs for an organizational application of wireless PDAs, and an equivalent third interface for desktop computing. Third, the interface designs are evaluated based on performance and usability through participant use and perceptions. Finally, the results are discussed and future research potential is outlined.

2 Literature Review

As multifunction devices increase in their functionality, they also increase in complexity. But as designers have been putting more and more features into smaller devices, the limits of user tolerance for these complex devices are being reached. There are two primary ways to create a usable and positive user experience in the face of growing features and functions (Kaplan, 2006). The first is to offer more than one version of the same product, as seen in the cell phone industry. The second way, to enhance the usability of multifunction devices and create a positive user experience, is to focus on user interface design (Kangas & Kinnunen, 2005). To do so, usability engineers need to focus on simplicity but with an emphasis in two interlinked areas; a) simplifying the interface design to ensure the fewest keystrokes, clear navigation, and ease of use; and b) examining user experience in terms of how various functions are used in practice, what functions are used together, the sequence of functions, and the expectations of the user. User field experience and data is an essential element in accomplishing this successfully (Holtzblatt, 2005).

Usability is one of a range of non-functional requirements, such as safety and security, which should be considered and satisfied as part of the design process (Ham et al., 2006). Therefore, it should be properly specified during requirements analysis and designed during the architectural and implementation design phases. Conversely, usability is the concept that needs to be evaluated from a user-centric point of view. User perception of usability is influenced by many design factors including visual appeal, hedonic qualities, logical task sequences, and pleasure in use, as well as contextual factors including user environment (i.e. context of use). Formative evaluations are needed to obtain user feedback during the early designs of mobile systems, while summative evaluations are more formal processes to document usability characteristics through testing by users (Scholtz, 2004). Both forms of evaluation were used in the design and development of the interfaces discussed in this paper; although the main results reported are from the summative evaluation.

The unique features of mobile devices and wireless networks pose a number of significant challenges for examining usability of mobile applications, including mobile context, multimodality, connectivity, small screen size, different display resolutions, limited processing capability and power, and restrictive data entry methods. Addressing these issues involves usability testing of mobile applications that target questions such as (Zhang & Adipat, 2005): the use of specific presentation methods to help users to search for/browse/understand specific information; appropriate designs of menu and link structures for easy navigation; supporting specific activities through mobile application; data entry methods that are the most efficient; the development and use of mobile applications considering mobile context, mobility, and network connection speed. These issues are addressed separately below.

2.1 Presentation Methods

For mobile consumer applications, where access is voluntary, it is important not just to shrink Web pages to fit a cell phone or PDA screen (Venkatesh et al, 2003). Design efforts should also ensure easy site navigation, with users being able to find relevant content with minimal effort. This can be accomplished with simple menus, forms, or icons, with one suggested key to success being the ability to present content to users in a customized fashion (Venkatesh et al., 2003). However, consumer goals for wireless mobile applications are not likely to be the same as those applicable to a Web (PC-based) context, since a wireless context may involve time or location pressure as deciding factors.

The small size of mobile device displays gives rise to problems of efficiently displaying and organizing as much information as possible (Seong & Broga, 2006). This limitation has a significant impact on other characteristics when designing a usable mobile interface, including the problem of too much paging within a screen, thus increasing the complexity of the interaction. However, negativity towards small screens tends to be uninformed. Small screen size does not necessarily lead to poor readability, comprehensibility or ineffective interactions (Buchanan et al., 2001). Small screens on mobile devices are effective for short focused pieces of information, so this is how they should be used. To work with small display sizes, large pages must be segmented into smaller well-organized and inter-related chunks, where the display area of interest does not exceed the screen size.

2.2 Navigation Designs

Content discovery in mobile consumer applications continues to be a major problem due to the navigation effort required (Smyth et al, 2008). Several techniques have been proposed and compared for navigation on small-screen devices, where the user can simultaneously pan and zoom (Burigat et al, 2008; Jones et al, 2005). Users respond positively to these systems, but the reduced screen space reduces their impact in comparison to reported studies on standard desktop screens. Users of such systems run the risk of getting lost in the information space presented when navigating on a display of a small section of a larger region. However, most mobile organizational applications do not involve large information spaces that are unfamiliar to the user, so searching and browsing becomes less important. Here the user is typically aware of what is available and how to access that content through specific displays. In organizational applications, where navigation is likely to be of greater concern than search, the designer needs to focus on the appropriate designs of menu and link structures that help users to reach a destination page more easily. This requires menus and link structures that are sufficiently simple and straightforward. General guidelines for menu and link design include (Zhang & Adipat, 2005): First, menu choices should be clear with easily interpretable labels, consistent throughout a navigation site, and predictable so that users can foresee results of actions based on their past interaction history. Second, designers should avoid displaying a long list of choices on the screen in order to minimize user cognitive load. Third, a structured menu should facilitate users to finish tasks with minimum device interaction (e.g., scrolling, data trees, and button clicks).

There are two main mechanisms to navigate to a desired page on a mobile device:
1) initiating an action to reach that page by clicking on the appropriate link. It has been suggested (Buchanan et al., 2001) that mobile device page navigation might be simplified by using simple hierarchies like existing phone menus with which users are already comfortable, and decreasing the number of keystrokes required, and/or replacing text input with menu selection. This approach compares unfavourably with a grid layout of options (Christie et al, 2004), unless the complexity of choice is high.
2) scrolling to the appropriate page. This approach is ineffective if content is not pruned such that only immediately relevant material is being displayed (Venkatesh & Ramesh, 2006). It is also important to display the information in related chunks such that more closely relevant information can be viewed at one time on the screen.

Buchanan et al (2001) compared vertical scrolling, horizontal scrolling, and paging for presenting general news and information for consumers on mobile WAP (Wireless Application

Protocol) phones. They found that vertical scrolling performed better in terms of efficiency, but with very little statistical difference between results observed among the three techniques.

2.3 User Activity Support

Mobile support technology for organizational applications can be categorized along five dimensions: portable processing power, mobile communication, mobile online information access, mobile job dispatch, and location-aware services (Zheng & Yuan, 2006). This paper investigates mobile online information access specifically for a mobile information access application that supports supply ordering transactions by home healthcare nurses.

2.4 Mobile Context, Mobility, and Network Connection and Access Speed

Considerations of mobile system interaction include (Seong & Broga, 2006): computing and software architecture involving features and appropriateness of wireless mobile technology such as weight, screen size, resolution, bandwidth, memory and processing power, availability and flexibility; context of use, ability to adapt, and sensitivity to surroundings; and personalization aspects that allow creativity and flexibility when browsing wireless portals. No matter how well the interface is designed, usability also depends on making network connections, and the access speed when connected to the network. It is difficult to install wireless networks in a way that provides complete coverage where users operate their mobile devices. Obstacles such as buildings, walls and even people offer varying amounts of attenuation to the propagation of radio waves. The result is spotty coverage that interrupts network connectivity for users.

The most important aspect of the design process is to provide the user with a real usage context. For mobile applications, users need to be able to touch the buttons and see software that feels like it is actually working through a prototype design (Kangas & Kinnunen, 2005). Clearly, finding the most usable choice for users of a particular functionality in a particular environment needs to be well thought out and tested, and will determine the success or failure of the application in displaying usable and presentable information on a small screen.

3 Usability Design

3.1 Mobile Application System Development

The development cycle for a wireless mobile system is not unlike development cycles for other information technologies. However, because of the specialized nature of the mobile devices, and since other factors such as network availability and access play such a significant role, user perceptions of usability must be evaluated continuously throughout the development process (Kangas & Kinnunen, 2005) in order to improve opportunities for successful outcomes. Usability should enter into consideration during requirements analysis, design and initial paper prototype, pilot implementation and internal testing, design revisions and system acceptance testing, and finally field implementation.

3.2 Usability

Usability is defined (ISO, 1998) as the quality of use: "The effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments". Reliable measures of overall usability can only be obtained by assessing the effectiveness, efficiency, and satisfaction with which representative users carry out representative tasks in suitable environments (Bevan, 1999). Nielsen's framework of system acceptability includes usability is a part of usefulness and is composed of: Learnability; Efficiency of use; Memorability; Few and non-catastrophic errors; and Subjective satisfaction (Nielsen, 1993). Studies of user behaviour on the Web have found a low tolerance for difficult designs or slow sites (Nielsen & Norman, 2000) and this would be expected to carry over to any online wireless application. Any application, no matter how sophisticated, will not be adopted successfully unless the end-users find it easy to learn, easy to use, and helpful in supporting their work. Otherwise, users may become frustrated and leave before their objectives are accomplished (Tarasewich, 2005).

Usability guidelines suggested by Buchanan et al (2001) for WAP service development can apply to small screen wireless devices in general. These include:

1. Develop services that provide direct, simple access to focused valuable content. Usable and useful services give the user key, summarized information with very few keystrokes or text entry. Simply converting conventional Web material to small device platforms will fail.
2. Trim page to page navigation to a minimum; use simple hierarchies.
3. Reduce the amount of vertical scrolling by simplifying the text to display.
4. Reduce the number of keystrokes expected from the user. This can be done by simplifying navigation and by replacing text input with other types of interaction method (e.g., menus).
5. Combine theoretical and empirical evaluation to provide further insights.

4 Wireless Mobile Systems

4.1 Portal Technology

Web portals provide the ability to collect and display information from multiple sources and create a single point of access to information - a library of categorized and personalized content (Winkler, 2004). This helps to manage a core challenge faced by Web developers, which is the integration of disparate user content into seamless Web applications and well-designed user interfaces. Mobile portals differ from traditional Web-based portals through a greater degree of personalization and localization. The unique characteristics of mobile portals can include (Clarke & Flaherty, 2003): the need for ubiquitous access by wireless mobile users; the agility and accessibility that requires convenient access; the need to know the geographical location of users, upon which new location-based services are developed; and personalization requirements for individual wireless device users. Portal technology provides a framework to build applications for the Web, aggregating content and functionality (Credle et al., 2004).

Portlets are the building blocks of portals. The term "portlet" refers to a small portal application usually depicted as a section (normally not visible as a separate component) of a full Web page. Web pages, Web services, applications, and syndicated content feeds can be accessed through portlets. Any particular portlet is developed, deployed, managed, and displayed independently of other portlets, which are assembled into portal pages that, in turn, make up portal implementations. However, portlet functionalities may and often do communicate with one another. Portlets may be only a small piece of a larger presentation, and each portal page is potentially the aggregation of several portlets. The application of portal technology is highly relevant to wireless organizational applications – especially those that may be displayed in a variety of contexts. For example, a full portal display may be used for a normal desktop environment, while the component portlets, with appropriate content, size, and navigation design, may be used for small screen wireless individual displays.

4.2 Wireless Mobile Devices

The capability of wireless PDAs falls between desktops and cellular phones. PDAs do not have the broad bandwidths, stable connections and high computational power of desktops, but they do have adequate memory and resolution for displaying lower resolution color pictures. Through software stored in flash memory, they can support many types of file formats. From the usability aspect, the same content displayed on different client devices will have a different look and feel. On Web portals, a page may be composed of carefully arranged portlets, where every portlet occupies just part of the screen; although a portlet occupies much less real estate than regular Web pages, it may fill an entire PDA screen. This portal capability offers opportunities to create different displays for different devices, while keeping the component portlets unchanged, to maximize portlet reusability. For small display real estate such as PDAs, a menu can allow users to choose individual portlets to display. This research is directed towards a study of portlet displays for different devices to improve their usability for small display devices.

In this research, we carried out experiments that tested application usability on a PDA (HP iPAQ Pocket PC hx2400-Series), and participants compared this with a full screen display in a desktop environment. PDA input was through a touch screen with the aid of a stylus, while interaction with the desktop display was through a desktop mouse. This PDA has a diagonal screen size of 3.5 inches (89 mm), roughly the same size available on many smartphone devices. Data were gathered to measure evaluator response to individual environments, and differences between their perceptions and their performance in each environment, to evaluate relative usability.

5 Supply Ordering System and Mobile Computing

This research was motivated by the potential for homecare nursing to use wireless access to remote systems to support and document their work. Since nurses spend more than 50% of their time documenting work and communicating with colleagues and supervisors (Archer et al, 2007), any increase in the efficiency of these activities can have a significant impact on the efficiency of these activities. Mobile computing can revolutionize the way nurses provide care at the bedside or in the home. It can improve nursing productivity, quality of care, and efficiency, while at the same time increasing patient safety and reducing risk of medical errors. With mobile computing, nurses can (Malkary, 2004): Generate structured clinical documentation; Access information on-demand; Facilitate real-time communications with team members; and Practice evidence-based nursing.

Mobile computing devices make it possible to access multiple clinical applications at the point of care, enabling nurses to access patient electronic medical records; generate structured patient documentation; and initiate supply orders when necessary. From the possible homecare nursing applications that were needed in this particular home care organization, supplies ordering was ranked as the most important application by the project group and was selected for the initial study. The project's formative implementation considerations have been reported elsewhere, providing field guidance for redesign (Archer et al., 2007). Future extensions, with the system infrastructure in place, can support multiple functionalities through the same portal.

5.1 Requirements Analysis

In the research study, we utilized three methods to perform software requirements analysis: stakeholder interviews, requirements workshops, and use cases. In order to keep all these discussions well organized and efficient, we documented the evolving requirements as they emerged. We interviewed stakeholders, ranging from management teams to homecare nurses and technical personnel. Different users have differing or even contradictory requirements. This helped to reveal major discrepancies with regard to how the existing business process works and how it should work in the future. After requirements of the user community were collected, organized, and presented to the users, requirements specifications were signed off through mutual agreement.

5.2 System Design

The design of the main system, including implementation and testing has been discussed elsewhere (Archer et al., 2007). The prototype was developed over a period of time with the involvement of homecare nurses who provided valuable initial input, and feedback on application design and field testing (Zhang et al, 2008). The purpose of this paper is to present the summative evaluation of the wireless mobile interface designs in a controlled laboratory environment, which reflects system design after a great deal of user input and preliminary testing.

The research project resulted in a prototype supported by portal technology, with one Web page that included five portlets. These portlets could be laid out within one page to support supply ordering and the related business logic in a full screen display. Any portlet could be viewed by selecting it on the Web page. Conversely, the portlets could be displayed separately on small screen displays, where they still communicate with one another through the mobile portal. Supply ordering was supported by five interdependent portlets: Client List Portlet, Client Details Portlet, Catalogue List Portlet, Catalogue Item Portlet, and Requisition Form Portlet. Since the portlets were reusable components, these portlets might be used in other homecare nursing applications as well. Portlets could run independently from each other, but they could also communicate with each other.

Client list portlet - displays a list of clients that the homecare nurse needs to visit in the current day. Each entry includes client last name, first name, gender, HCN (health card number), etc. and can be sorted by column.

Client details portlet - displays detailed client information, such as the version code of HCN, the case manager's name, etc., including data that do not appear in the client list portlet. The client details portlet can accept the health card number as a key to query detailed patient information.

Catalogue list portlet – displays a full listing of the medical supply catalogue, which has less than one hundred catalogue items. It can be sorted by catalogue item name or number.

Catalogue item portlet - displays detailed catalogue item information, such as units per package, restrictions, specifications, etc. that do not appear in the catalogue list portlet display.

Medical supply requisition portlet - maps the medical supply requisition list, and includes three related components: nurse information, patient information, and the shopping cart which includes all catalogue items and their quantities to be ordered for the current patient. Nurses can place orders after all the data have been selected properly, and content is confirmed by clicking the "proceed to checkout" link. This portlet thus features the ability to receive messages from the other four portlets. The logical and communication linkages among the portlets are shown in the transition state diagram in Figure 1.

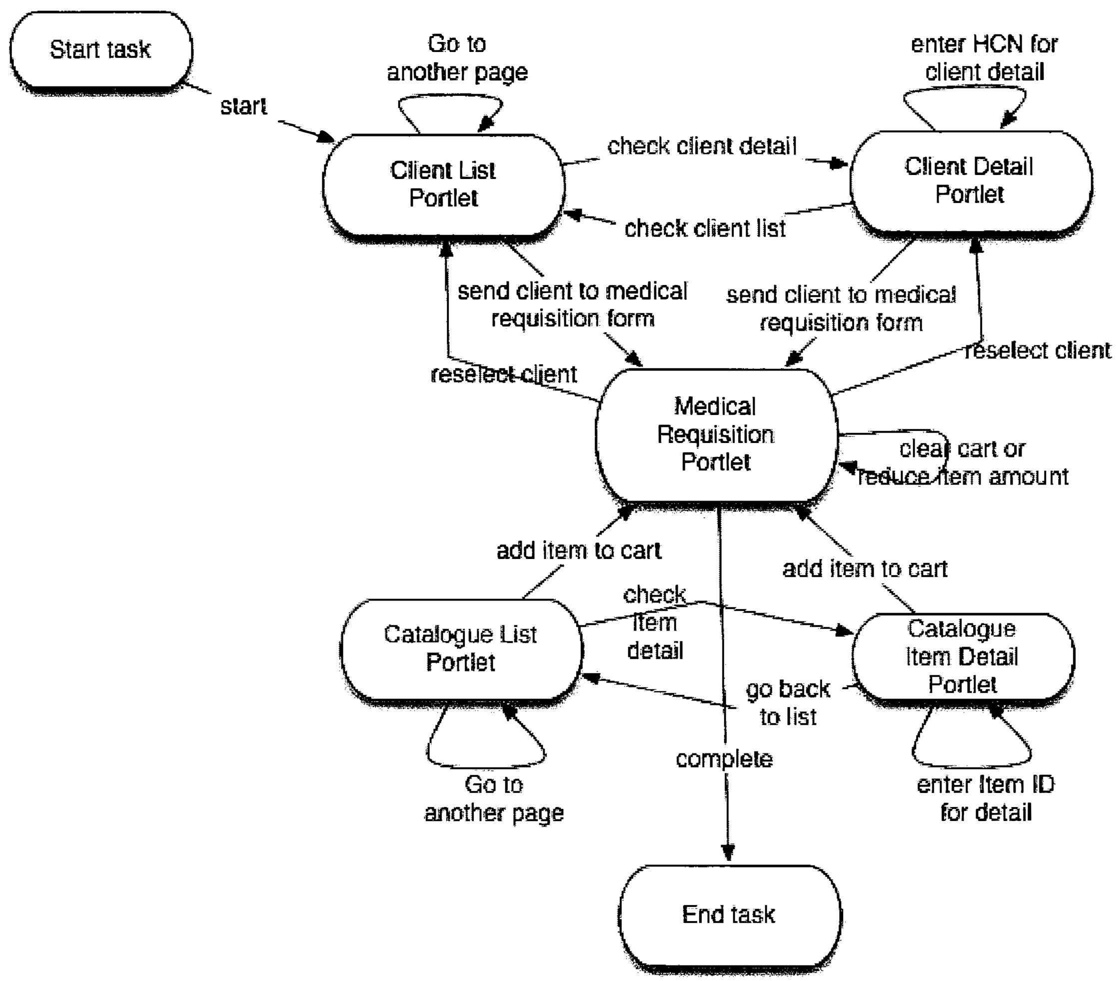

Figure 1. Supplies Ordering Transition State Diagram

5.3 Interface Versions

The main purpose of this study was to compare usability perceptions of three versions of the interface that could be operationalized through the online portal. In the PC version of the application, the portlets appear simultaneously in a logical arrangement on a PC desktop screen (see Figure 2), although some scrolling was required to access the content of all the portlets displayed. This version is referred to as the PC Full version. The PDA Scrolled interface version (see Figure 3) was similar in design except that, of course, not as much content was visible on the PDA screen. Thus more scrolling would be required (horizontal and/or vertical) to display the desired content. The PDA Menu interface version (see Figure 4) presented menus that users could select to move from one portlet to another as the required tasks were performed.

Although the interface versions differ somewhat in their display appearance, there is no difference in their state transition diagrams. In effect, being at any particular state, the user could go to another desired state either by pointing with the stylus to a menu that allows a jump to another desired portlet (menu version), or by scrolling to another desired portlet (scrolled version). Although the actions were different (menu selection versus scrolling), the end results were the same for both PDA versions. The PC Full version was similar to the PDA scrollable version except, of course, less scrolling was necessary to get to the desired portlet since most of the portlets were displayed simultaneously on the larger screen.

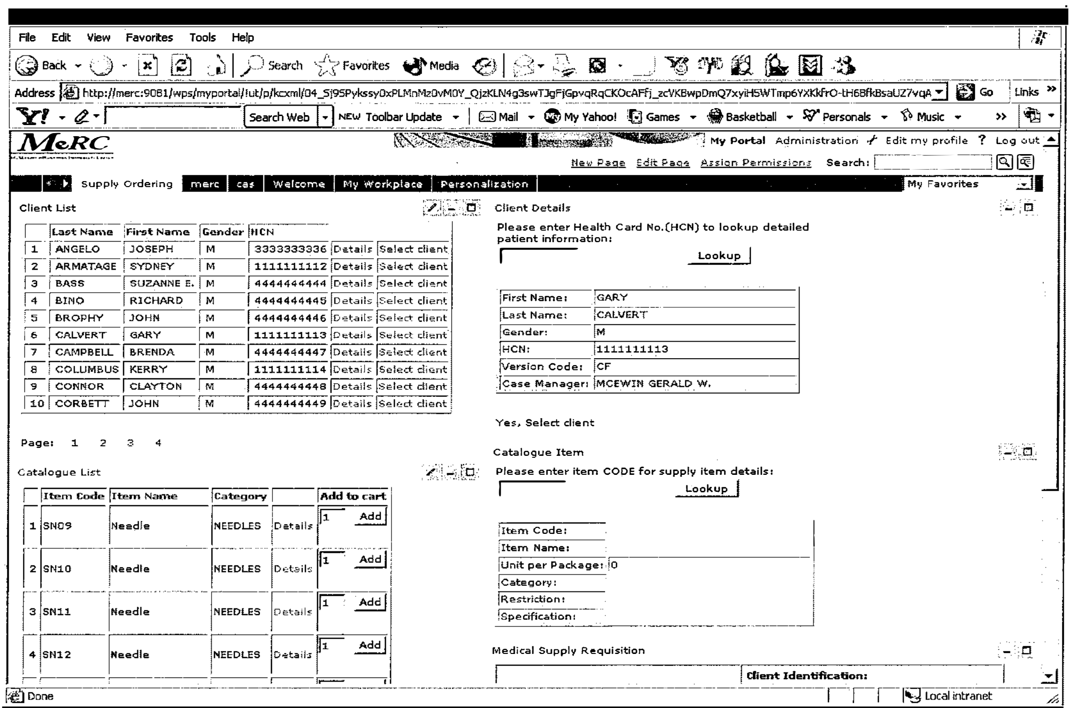

Figure 2. PC Full Version

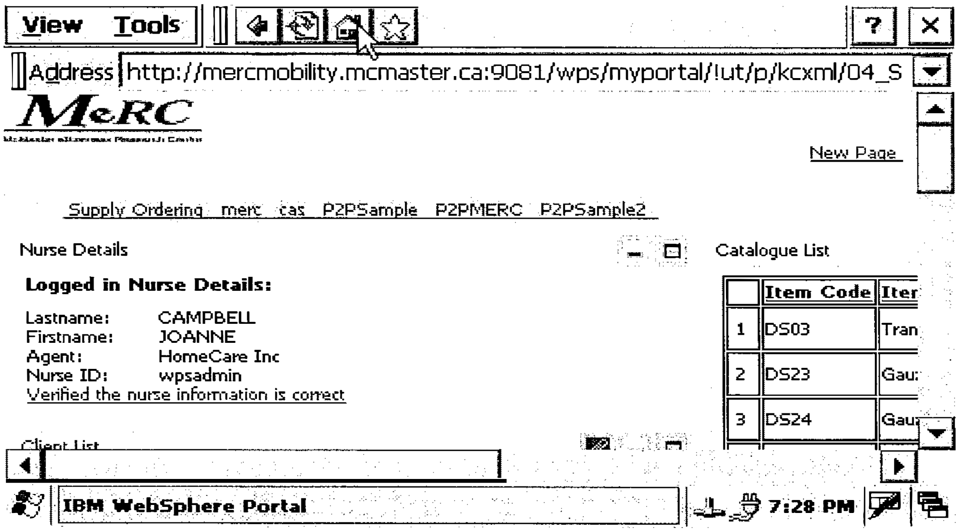

Figure 3. PDA Scrolled Interface Version

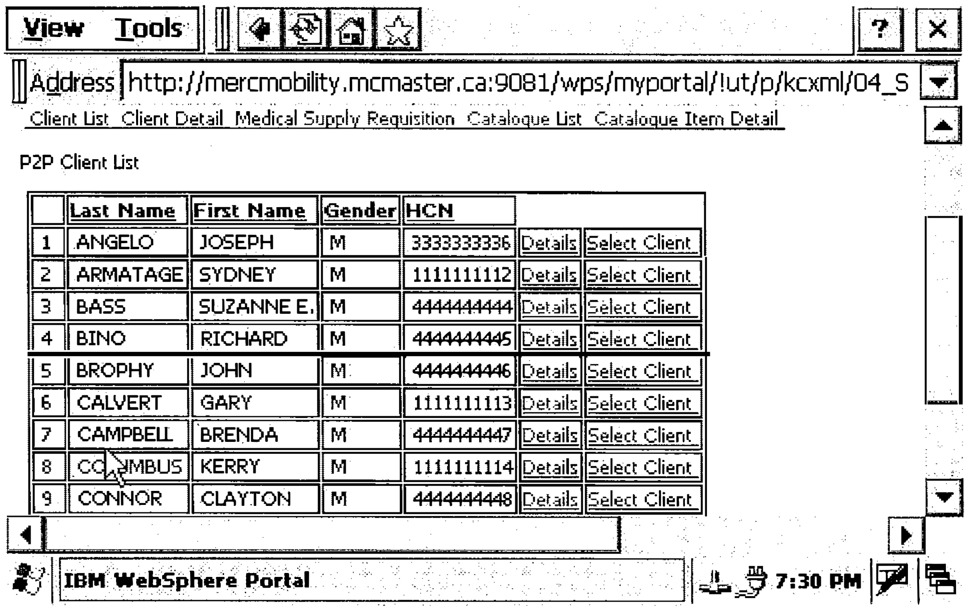

Figure 4. PDA Menu Interface Version

6 Hypothesis Development

There is a great deal of conflicting evidence from the literature on wireless mobile device interfaces. Some of the limitations of the literature that pertain to the current research is that most published research is on applications where the ability to search is critical. However, there seems to be general agreement that, unless an application is be easy to learn, easy to use, and helpful in supporting their work, users may become frustrated (Tarasewich, 2005). How to accomplish this leads to the two major issues of content display and navigation on small screen devices.

Content Display The ergonomics challenges of small screen sizes relate to the visual acuity of the human eye (Pagani, 2007). This causes problems when attempting to display Web content more suitable for full-sized computer screens, limiting the efficient display and organization of information (Seong & Broga, 2006). This limitation has a significant impact on other characteristics when designing a usable mobile interface, including the problem of too much paging within a screen, thus increasing the complexity of the interaction. However, small screen size does not necessarily lead to poor readability, comprehensibility or ineffective interactions. To work with small display sizes, large pages must be segmented into smaller well-organized and inter-related chunks, so that the display area does not exceed the screen size (Buchanan et al., 2001). Transferring traditional PC applications successfully to a small screen requires the implementation of simple navigation devices, and retaining only what is needed in a mobile setting.

Navigation There are two major approaches to small screen navigation. First is the use of simple menus, forms, or icons (Venkatesh et al., 2003) to find relevant content. Menu choices should be clear with easily interpretable labels, consistent throughout a navigation site, and predictable so that users can foresee results of actions based on their past interaction history (Zhang & Adipat, 2005). Designers should avoid displaying a long list of choices on the screen in order to minimize user cognitive load, and a structured menu will facilitate users to finish tasks with minimum device interaction (Zhang & Adipat, 2005). Mobile device page navigation might be simplified by using simple hierarchies like existing phone menus with which users are already comfortable, and decreasing the number of keystrokes required, and/or replacing text input with menu selection (Buchanan et al., 2001). However, this approach compares unfavourably with a grid layout of options (Christie et al., 2004), unless the complexity of choice is high.

The second general approach to small screen navigation involves navigating directly on the screen display through scrolling, panning, or zooming to find the desired information or data entry point on the screen. There have been several studies of panning and zooming (Burigat et al., 2008; Jones et al., 2005). Users respond positively to these systems, but the reduced screen space reduces their impact in comparison to reported studies on standard desktop screens. The amount of scrolling can also be reduced by simplifying the text to display (Buchanan et al., 2001), and scrolling to the appropriate page is ineffective if content is not pruned such that only immediately relevant material is being displayed (Venkatesh & Ramesh, 2006).

Buchanan et al (2001) compared vertical scrolling, horizontal scrolling, and paging (a variant menu application) for presenting general news and information for consumers. They found that vertical scrolling was more efficient, but there was very little statistical difference between results observed among the three techniques.

Finally, access speed will also play an important role. Users have a low tolerance for slow sites (Nielsen & Norman, 2000).

Based on the existing literature, we can formulate research questions that relate to the different approaches (menu versus scrolling) to the design of small screen interfaces in the context of organizational applications.

Research Question 1: What is the most efficient interface?

Research Question 2: What is perceived by users to be the most usable interface?

Search applications are not an issue in this study since the content displays have been chunked appropriately for all three interfaces through the use of portlets within a mobile portal, although display size remains an issue since it determines the amount of navigation required in each interface. Navigation and access speed are therefore likely to be the determining factors in this study. Efficiency will be negatively affected by smaller screens and the need to navigate among the different functionalities being used. This suggests

Hypothesis 1: The PC Full version will be more efficient than the PDA versions of the interface.

Based on the faster access speed and the more convenient and complete display with very little scrolling on the PC Full version leads to

Hypothesis 2: The PC Full version will be preferred to the PDA versions of the interface.

Almost all small screen interface results have been for consumer and search applications. Based on the limited results from these applications (Buchanan et al., 2001) this suggests

Hypothesis 3: There will be no conclusive preference between the PDA menu interface and the PDA scrolled interface.

7 Experimental Study

Usability testing of a product can be conducted in a lab environment if the end-user tasks are not related to a specific mobile context (Kangas & Kinnunen, 2005). The main objective in this research was to compare the usability of the three versions of the online application, based on the limited display of small screens and their impact on user perception of application usability.

Tullis and Stetson (2004) compared the reliability of several usability questionnaires in typical Web site usability tests, and concluded that the SUS (System Usability Scale) (Brooke, 1996) yielded among the most reliable results across the sample sizes they used, with sample sizes of at least 12-14 participants needed to get reasonably reliable results. The SUS instrument was therefore chosen for this study (see Appendix 1).

7.1 Participants

Participants were recruited by word of mouth and through e-mail, and were compensated with the nominal sum of $10 for participating in the experiment. There were 18 participants, mostly graduate students. Nielson suggested that 5 end-users could discover 80 percent of the usability problems (Nielsen & Landauer, 1993), but we needed enough users so we could evaluate statistical differences among the perceptions of participants as they performed their tasks with different interface versions.

Participants in the study were well educated; 39% had undergraduate degrees and the remaining 61% were graduate students. None had nursing experience, so the application they were evaluating was entirely new to all participants. 72% claimed little or no experience in the field of human computer interaction, while 22% claimed to be experienced and only one participant claimed to be very experienced. 17% said they had no experience in using a pocket PC, PDA or cellphone to access the Internet, 55% said they had little experience, but 28% said they were experienced in accessing the Internet this way. 78% said they owned a pocket PC, PDA, or cellphone.

7.2 Experimental Design

The laboratory tasks were performed by participants seated at a desk, since this not unlike the typical environment in which home healthcare nurses work (i.e. they are not actually 'mobile' and moving around while using the devices (Kjeldskov & Stage, 2004)). Each participant was given a short training session in accessing and retrieving information through the interface before starting to carry out the assigned task in each case. Each participant completed a set of experimental tasks using the prototype, each with three different interface designs. This was done in one of the six possible permutations of the order in which the three interfaces could be tested, in order to minimize the impact of learning effects on the results. The 18 participants provided three repeats of each possible permutation. Each participant performed a different task scenario with each of the three different interfaces, using a mouse with the desktop version, and a stylus with the two PDA versions (scrolling and menu versions respectively). Appendix 2 discusses, with examples, a task scenario that could be chosen at random from the six available. An attempt was made to keep task completion time roughly the same among the scenarios. The evaluation scenarios were carefully selected to have similar workloads.

7.3 Data Collection and Analysis

Evaluators completed three SUS usability forms (see Appendix 1); one for each interface test they performed, immediately following test completion. Comparison data were also collected from the evaluators after completing all of their evaluation scenarios, where the three interfaces were ranked 1, 2, or 3 on each of the ten SUS statements, in declining order of preference. An eleventh ranking gave each evaluator's overall ranking of the three interfaces. These data were used to make usability comparisons among the three interfaces.

Loading time differences can affect efficiency comparisons between interfaces. Because the PC Full interface was linked to the system through the Internet, the effective loading time for this interface was effectively zero. The average loading time for menu pages in the PDA menu-driven interface was 2.1 seconds, while the PDA scroll-driven interface loaded in 6.8 seconds. However, since the menu-driven interface required a minimum of five page loads to accomplish any particular task, total loading time for the menu-driven interface tasks results in latencies that were longer than for the PDA scroll-driven interface.

Task completion data were also collected for efficiency measurement purposes. Table 1 shows the means and standard deviations of completion times for tasks using the three interfaces, for all 18 participants.

Table 1. Participant Task Completion Times (seconds)

	PC Full	PDA Menu	PDA Scroll
Mean	246.44	271.22	298.72
Standard Deviation	22.59	18.23	31.20

The Friedman two-way analysis of variance by ranks for matched samples (Siegel & Castellan, 1988), p. 174 was used to test for differences among the participant completion times. An overall difference was detected ($p < .01$), but there was a significant difference only between PC Full and PDA Scroll completion times ($p < .05$).

Thus, Hypothesis 1 was partially rejected. That is, the PC Full interface was more efficient than the PDA Scroll interface but not more efficient than the PDA Menu interface, regardless of the longer total loading times for the PDA Menu version. The indication here is that scrolling rather than loading (even when only one loading was required) slowed down the PDA Scroll interface.

SUS scores on each of the 10 statements in the data collection instrument were based on a five-point Likert scale (see Appendix 1). The SUS score from each evaluator for each interface was calculated from a formula provided by the SUS developer, which includes reversing the even numbered statements (Brooke, 1996) (see Table 2). To determine the statistical significance of the results, the Friedman Two-way Analysis of Variance by Rank for matched observations (Siegel & Castellan, 1988) p. 174 was employed to test the null hypothesis that the three interfaces were drawn from the same population. An extension of the test (Siegel & Castellan, 1988) p. 180 was then used to determine the order of perceived usability performance and the statistical significance of the ordering. The statistical analysis showed that PC Full was preferred to PDA Menu and to PDA Scroll ($p < .05$), but that there was no significant difference between PDA Menu and PDA Scroll.

Table 2. SUS Evaluator Score Results

	SUS Scores		
Evaluator	PC Full	PDA Menu	PDA Scroll
1	72.5	65.0	60.0
2	50.0	50.0	27.5
3	90.0	77.5	77.5
4	70.0	50.0	75.0
5	87.5	75.0	57.5
6	90.0	70.0	77.5
7	60.0	52.5	35.0
8	85.0	60.0	70.0
9	87.5	72.5	67.5
10	62.5	52.5	40.0
11	82.5	42.5	62.5
12	97.5	75.0	47.5
13	95.0	92.5	75.0
14	90.0	77.5	50.0
15	97.5	72.5	55.0
16	90.0	45.0	82.5
17	97.5	82.5	52.5
18	100.0	82.5	62.5
Averages	83.61	66.39	59.72

After completing the three sets of tasks, one for each interface, participants compared the three interfaces on the 10 SUS statements, plus an overall comparison statement 11. Table 3 shows the analysis of the resulting data with a non-parametric multiple comparison test (Siegel & Castellan, 1988) p. 180, with the key finding (shown in column 4) that, in all but one of the SUS statements and for the overall result, the differences between the preferences for the PDA Menu and the PDA Scrolled interface were not significant. In addition, the PC full screen interface was preferred significantly to the PDA Menu interface for all but one statement (column 2), and the PC full screen interface was preferred significantly to the PDA Scrolled interface (column 3) for all but four of the SUS statements.

Table 3. Interface Comparisons for SUS Statements

SUS Statement	PCF > PDAL	PCF > PDAS	PDAL > PDAS
1	**	**	ns
2	**	ns	ns
3	**	**	ns
4	**	ns	*
5	ns	**	ns
6	**	ns	ns
7	**	**	ns
8	**	*	ns
9	**	**	ns
10	**	ns	ns
Overall	**	**	ns

Notes: > = preferred to
* = p < .05 (1-tailed multiple comparison test (Siegel & Castellan, 1988) p. 180)
** = p < .01 (1-tailed multiple comparison test)
ns = not significant

Based on the results from the experiment, the standard PC Full screen display of the portal was preferred to both of the PDA versions on all the overall measures, so Hypothesis 2 was not rejected. Since there was no significant overall difference between evaluator preference for either of the PDA interfaces, Hypothesis 3 was not rejected either.

More insight can be gained by mapping the SUS results to the Nielsen usability factors, although these statements do not map one to one (Nielsen, 1993). The relationships between SUS statement results and Nielsen usability factors are shown in Table 4, along with the averages from the combined SUS measurements for the three interfaces.

Table 4. Average SUS Scores Mapped to Nielsen Usability Factors

Nielsen Usability Factors	Applicable SUS Statements	PC Full	PDA Menu	PDA Scroll
Learnability	4,7,10	3.61	2.96	2.83
Efficiency of Use	3,5,8	3.28	2.44	1.91
Memorability	2,6	3.03	2.61	2.75
Few & Non-Catastrophic Errors	Not Applicable			
Subjective Satisfaction	1,9	3.36	2.56	2.09

The largest differences among the different interface versions were in Subjective Satisfaction and perceived Efficiency of Use, while the smallest differences were in Learnability and in Memorability. This may be due to the use of portlets as building blocks; they appear in all three versions that were evaluated. The participants saw these versions as similar, improving ease of learning and memorability, but because their navigation was different, they had a larger impact on subjective satisfaction and on efficiency of use.

8 Discussion and Future Work

Online wireless support for mobile workers is an increasingly important issue, and the design of interfaces for online functionality can have a major impact on the acceptability of these systems to users. Mobile portals are one way of providing support that can be flexible in many ways. Since a portal can be built out of portlet "building blocks", this creates highly flexible solutions. In the application described in this paper, portlets could be displayed either meshed together as one or more entities or as separate independent entities. This makes it feasible to display the functionality of the portlets as combined entities on a normal desktop computer screen or on a wireless portable device. In both cases, a certain amount of scrolling may be required to navigate to the point of interest, but with a greater likelihood that the user could get lost on a small screen interface.

In this study, we found (no surprise) that the full PC interface version on a desktop screen was preferred to the two PDA interfaces. However, we did not find a significant difference between user preferences between the PDA Menu and PDA Scroll interfaces. This is a result that is significant for organizational application development. It may also be important to consider another advantage of small screen scrolling applications in that they present displays that are similar to a full PC display. A user working alternatively in an office and mobile situation may find this very useful because the displays are similar.

Limitations of this study include: first, this experiment was conducted with a Wi-Fi system that had a wide bandwidth, rather than over a mobile phone network which typically has a relatively low bandwidth. Extrapolating these results to a mobile phone network is probably not valid, due to higher page download times on the mobile network. Second, we used a thin client system, where all pages were generated and/or downloaded from the server on request. Thin clients tend to have problems due to potential dead spots when running over mobile phone networks. For mission-critical tasks, rich clients similar to the PDA scrolled version are more effective, since they support smoother and more continuous operations. On the other hand, security and privacy can become issues for applications that cannot be allowed to store data on mobile devices. In real situations, it is necessary to consider a range of options in order to make the most appropriate choice of device interface. The third limitation in this research is that our conclusions are based on a five portlet prototype. The result might be different if we had a larger number of portlets in the portal application and hence a larger and more complicated display. However, in such situations it may be possible to implement a zoom and pan system such as those developed for consumer search applications (Burigat et al., 2008; Jones et al., 2005) to avoid getting lost on the small screen display.

This research has shown the flexibility of mobile portals for organizational wireless applications. As wireless applications become more ubiquitous, there is a need for research into models that are suited specifically to this environment and its particular needs. Further research is also needed to address the broader but related considerations of adoption, and how it relates to interface design. The entire area of integrated design of mobile systems that can be used in both desktop and mobile versions is in need of more detailed investigation.

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Appendix 1: SUS Usability Form [1] (Brooke, 1996)

Evaluator No: _____   Application No. _____

Legend: Strongly Disagree: SD; Disagree: D; Neutral: N; Agree: A; Strongly Agree: SA

		SD	D	N	A	SA
1	I think I would like to use this application frequently					
2	I found the application unnecessarily complex					
3	I thought the application was easy to use					
4	I think I would need Tech Support help to use this application					
5	I found the various functions in the application to be well integrated					
6	I thought there was too much inconsistency in this application					
7	I believe that most people would learn to use this application very quickly					
8	I found the application very cumbersome to use					
9	I felt very confident in using the application					
10	I need to learn a lot about this application before I could effectively use it					

[1] "SUS has been made freely available for use in usability assessment, and has been used for a variety of research projects and industrial evaluations; the only prerequisite for its use is that any published report should acknowledge the source of the measure." Quote from (Brooke, 1996)

Appendix 2. Sample Test Scenario

Three scenarios were selected for each evaluator from among the six available to assess the usability of the interface prototypes. These scenarios were typical, realistic, and covered the main functions of supply ordering in daily homecare nursing, and the workloads were carefully selected to be as similar as possible (they could not be exactly the same, in order to reduce task learning effects as evaluators worked through the three interfaces).

In general, the workloads in each case were as follows:

Task One: Check a certain client's detailed information
Ex: Please find the Version Code for "Columbus, Kerry" Health Card Number (HCN).

Task Two: Confirm the selection of client "Columbus, Kerry"

Task Three: Check specifications of a certain supply item
Ex: Please find the specification for SN11 "Needle"

Task Four: Start shopping
Ex: Add 7 units of "Needle" with item code "SN10", (item code is case sensitive)
Add 4 units of "Tegaderm IV" with item code "DS72", and
Add 6 units of "Tape" with specification "Paper, 2.5cmm",
Change the order amount to 5 units for "Needle" with item code "SN10"; assuming that the (simulated) nurse realized that 7 units is more than the client needs.
Cancel the 4 unit order for "Tegaderm IV" with item code "DS72"

Task Five: Place the order

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