USABILITY ANALYSIS OF WIRELESS TABLET COMPUTING IN AN ACADEMIC EMERGENCY DEPARTMENT

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ABSTRACT

OBJECTIVE: To perform an economical and efficient evaluation of the usability of tablet computers in a clinical setting.

METHODS: A pilot-study modified discount usability analysis to determine benefits and limitations of a tablet computer used by physicians and residents in an academic emergency department.

RESULTS: With the tablet computer, physicians and residents in the emergency department were able to readily have access to information anywhere, anytime. However, the weight of the device and its reliability severely reduced its acceptability. Successful use of the tablet computer is dependent on functional wireless infrastructure and adequate technical support. Furthermore, software that is optimized for touch screen interaction and integrated with health information software systems for easy access to multiple sources of information is vital for improved usability.

CONCLUSION: The discount usability method provides a rapid, cost-effective, and accurate analysis of the usability of wireless devices in clinical settings. Usability study of the wireless device elicited workflow issues within the workplace as a whole. The tablet computer is part of a larger mobile computing implementation effort, with usability issues that arise not only from form factor but also through the relationship of the device to the software, the technical infrastructure, and human factors in the environment in which the device is used.

A Background on Connecting to Disparate Clinical Systems Using Mobile Devices

Introduction

The backbone of a robust health information system is the ubiquitous availability of accurate, easily accessible, and easy to distribute health information. Unfortunately, the current status of information system implementation in the health sector is far behind other industries. Personal computers, while popular in the business realm as networked systems, were never widely adopted in clinical healthcare settings due to cost, work habits and technical limitations. However, mobile healthcare computing devices have now become prevalent. These devices include pagers and cellular phones for communication, as well as hand-held computers that can incorporate data and communication, such as personal digital assistants (PDAs) and tablet computers. Hand-held mobile devices may present an option in the challenge to provide improved information documentation and handling in healthcare. These devices assist in at least three major activities at the point of care: accessing information, recording information, and transmitting/communicating information. Mobile computing can give physicians the freedom to interact with both personal and professional information, which allows them to improve their productivity and, potentially, patient care.

Mobile Computing Background

Early attempts at mobile computing in clinical settings were mobile "evidence carts," consisting of evidence-based medicine (EBM) and medical reference materials stored in a laptop computer or paper inventories.[1] However, it was soon determined that

these "evidence carts" could not realistically be taken on bedside rounds, due to their size.[1] Doctors needed a mobile tool that provided them with EBM and other clinical resources at the point-of-care. The personal digital assistant (PDA) may just meet that need due to its mobility and technological features.

A PDA is a small, computerized device designed to be portable and easily accessed. It can capture, store, and manipulate a variety of information. It is basically a hand-held computer that is small enough to fit in the palm of your hand. PDAs have several important features that distinguish them from desktop and laptop computers (PCs), in addition to size differences. PDAs turn on almost instantly and crash less frequently than PCs. PDAs use a handwriting recognition system or on-screen keyboards to allow text input via a stylus on a touch-sensitive screen. PDAs can connect to PCs to exchange programs and data. This process is referred to as "hot-syncing" and is commonly done via a "cradle" device connected to a PC. Most PDAs also use wireless infrared transceiver ports to directly communicate with compatible PDAs and printers, in a process known as "beaming." Other means of data exchange are through the use of compact flash or other memory cards, as well as through wireless network connections. Of final note, two major operating systems (OS) exist for PDAs: Windows® CE and Palm®. The Palm® OS has become the defacto standard for medical professionals, and it has a majority market share overall.[2] However, Windows® CE pocket personal computers are rising in popularity.

PDAs have been available for approximately 10 years, but there has been a significant increase in the uptake of "palm organizer" technology in recent years.[3] Hardware improvement and more diverse software applications led to a 169 percent

increase in sales from 1999 to 2000.[4] More importantly, out of their own interest, doctors have been a part of this boom.[5] According to a 2001 survey by Harris Interactive, Inc., 26 percent of the country's practicing physicians used hand-held devices for professional and personal activities last year.[5] Of even more interest, 33 percent of doctors not using PDAs at the time of the study expected to use them in the next five years. Based on these statistics, Harris Interactive estimates that 50 percent of the physicians in this country will be using the device by 2005.[5] Analysts from the investment bank W.R. Hambrecht in San Francisco take a more conservative numerical approach predicting the number of doctors using hand-helds at work will have reached 20 percent by 2004.[6] With either prediction, it is clear that PDA use is growing in clinical practice.

The movement toward PDA use in medicine began as a grassroots effort by the doctors, not by administration, and therefore is destined to continue its fast growth.[4] This becomes clear because it has been shown that if caregivers do not believe that a technology's benefits significantly outweigh its costs, they will not support it.[7] There are three main reasons for this rapid growth in PDA use by doctors: mobility, low cost, and the large breadth of applications available.[4] Another major reason that is rarely discussed in the literature may be user control, particularly the user's ability to easily configure the device. PDAs can replace having the white coat filled with mini-reference books, index cards and multiple scraps of paper. Most PDA devices are relatively inexpensive, putting them easily within the price range for the traditional early adopters of technology- young physicians and physicians-in-training.[4] Additionally, users can regularly download current clinical reference information that auto-updates for no additional cost.[4] Add to this the hundreds of niche applications that are available to be used to solve specific

clinical problems (many of them shareware), and you have a very powerful tool with a low entry cost.[8]

As it is clear that PDAs serve a use to doctors based upon their acceptance rate in the field, the benefits and limitations with this technology are still being determined. These devices clearly facilitate at least three major activities with clinical systems: accessing information, recording information, and transmitting/communicating information.[9] Many of the applications for PDAs utilize a combination of these activities depending on the technology in place.

Major Activities Performed Using Mobile Devices in Clinical Settings

Accessing Information

E-texts :

Medical electronic textbooks (e-texts) have been published for PDAs and would seem to be the logical means to access information in the highly mobile medical environment. The most popular e-texts include *5 Minute Clinical Consult, Harrison's Principles of Internal Medicine Companion Handbook,* the *Merck Index* and the *Washington Manual of Medical Therapeutics.*[2] However, many of these suffer in usability due to poor implementation to the smaller screen and the memory limitations of many PDAs. The plethora of software reflects the ease with which documents can be converted and stored on a PDA, rather than the demand for all such software/e-texts. Document managers enable users to convert documents from a PC into a PDA-readable file. In medicine, for example, pre-existing medical protocols from medical text file repositories can be converted into the format of a Palm® device- the doc format- for

mobile access.[2] Unfortunately, many times the key features of searchable text and file organization, such as found within databases, are lost using document manager programs alone. But, having to implement database managers in conjunction with document managers adds another level of abstraction and this has its pitfalls.

Drug Databases:

Because of its simplicity, ease of use, and database features, software for determining drug interactions and formulations has shown the effectiveness of mobile devices to access information. By far the most popular and well known is ePocrates® for the Palm® OS.[10] It is updated weekly on the Internet and offers a free version and a "pro" version, which has added functionality including clinical tables and alternative medicine information.[10] This software allows doctors to provide point-of-care prescribing, rather than having to look up drug information in a textbook or having to leave the patient in order to access a desktop computer to review the information. It can also reduce errors in prescriptions by helping physicians avoid adverse drug interactions, as well as reduce calculation errors with implementation of the included medical calculator function. Most adverse drug events are primarily caused by physician error, and many of these errors result from a problem with point-of-care drug knowledge.[11,12] Physicians have reported that ePocrates Rx® saves time during information retrieval, is easily incorporated into their usual workflow, improves drug-related decision making, and reduces the rate of preventable adverse drug events.[13]

Recording and Communicating Information

E-Prescribing:

The next technological step from using reference software to obtain drug information is to prescribe drugs electronically. Electronic prescribing of medication has its advantages, including reducing errors related to misinterpreting physician handwriting.[9] Furthermore it has been shown that computer-assisted prescriptions were more than three times less likely to contain errors and five times less likely to require pharmacist clarification than handwritten prescriptions.[14] Electronic prescribing however is still in its infancy because providers are expected to fund the systems and success depends largely on integration of systems, much of which has yet to be accomplished in the United States.[9]

Computerized Provider Order Entry/Coding/Charge Capture:

Electronic order entry is not limited to just electronic prescribing though. Computerized Physician/Provider Order Entry (CPOE) is a key project for many hospitals and clinics as a way of reducing medical errors.[15] Ideally, order entry should be done at the point of care, sometimes called bedside orders. PDAs offer the opportunity to not only provide bedside orders, but critical results, such as certain lab reports, could be received by the physician as soon as they are available.[9] However, point-of-care computing has just begun and the transition from handwriting to free text to interactive, structured documentation has been hampered by the lack of standards. In the future, it will likely be clinicians, not support staff, interactively recording structured information

at the point-of-care (physician order entry) and more than likely this will involve the use of a mobile device.[9]

Other applications utilizing a mobile device include automated coding and charge capture.[9] It is important to note that it is now technically possible to capture charges on a handheld device (e.g. comparing charges with CPT and ICD-9 codes), send the claim to the payer (e.g. via a wireless network connection), and receive responses or approvals before the patients leave the care location.[9,16] Physician order entry can go a long way to improving revenue by ensuring all relevant patient charges are captured.[16] The key to accurate and complete charge capturing is to collect information as close to the point of care as possible.[17]

Clinical/Administration Blended Functions:

Some additional functions of handhelds in medicine fall in more clinical/administrative blends. PDA-based software is available that tracks and manages referrals; manages resources, schedules and workflow; and generates invoices.[16] In Emergency Departments, mobile devices would allow practitioners to treat the patient immediately while admitting personnel with PDAs accompany the patient.[9] The result is more prompt care and higher patient satisfaction, because the patient does not have to wait through the time-consuming admitting processes before being triaged.[9] Other software packages are involved in ward management, patient tracking and patient logbooks.[8,18] In group practices or during hospital rounds, the PDA of each team member can be synchronized and patient information beamed between devices in an efficient "electronic handover."[2] This is a short-term solution though, as the eventual goal is to

integrate these with large-scale clinical databases and/or electronic medical records and work off a main server, utilizing the power of wireless networks.

Limitations of Mobile Devices in Clinical Settings

Integration:

Ultimately, mobile devices will be of little use beyond a reference source in medical settings without the use of database managers that are integrated with the electronic medical record (EMR) and/or clinical information system in place at the care facility. Many of the popular databases written for Palm® devices are simple and flat (e.g. Jfile and TealInfo).[19,20] However, there are some products, HandDbase in particular, that offer "relational" database features, although with technical limitations based on the fact that it is not a true relational database.[21-23] The "relational" features are important though as they allow clinicians the ability to better practice evidence-based medicine by constructing a patient-tracking system with links to drug details, differential diagnosis and medical procedures and protocol.[2]

The use of PDAs for point-of-care database entry has been successfully trialed in emergency medicine, clinical audits, clinical trials and for clinical encounter and procedure logbooks.[24-29] Furthermore, patients themselves have been provided with PDAs to document their own symptoms in real time.[30,31] However, while these stand-alone databases on PDAs have been show to work in trials, few systems have been designed as point-of-care additions to already existing enterprise clinical systems. It is far more likely that these database managers would be used in an integrated manner with legacy clinical databases or new electronic medical record systems. Therefore, the

development and implementation of PDA-based client/server patient data systems are likely the weakest links in the desire to expand PDA use to fully meet CPOE needs. [22,23]

Education and Usability:

It seems the PDA may soon become an essential medical instrument, as indispensable as the stethoscope, but there are some important limitations that deserve discussion. From a medical training standpoint, there is the need for junior practitioners to learn through experience and not rely on computers to make decisions.[18] While PDAs allow for easy menu choices and list options, medical educators argue that nothing compares to having to formulate one's own history, examination, investigations and problem list onto a blank piece of paper- and therefore close supervision is required during training.[18] On another usability issue, many clinicians don't like the small screens on the devices. Additionally, it seems that some tasks in clinical practice are just not appropriate for the PDA.[23] Beyond these basic issues, there seem to be three main interconnected issues: security, networking-interconnectivity of the devices with legacy systems, and interference issues with medical devices.

Security:

Security, particularly with the Health Insurance Portability and Accountability Act (HIPAA) regulations, is a major hurdle with mobile devices in the medical setting.[32] As vendor and provider communities struggle to define an end-to-end messaging flow that complies with HIPAA in traditional systems, they recognize that HIPAA compliance with PDAs and other mobile computing devices is even more complex.[9] Confidential

patient information on PDAs is a significant concern as these devices are small and can easily be misplaced or stolen.[2] There are a number of security programs that provide password control of confidential files.[2] Although this would help in making individual PDAs secure, it must be remembered that the PDA's contents are usually replicated on various PCs during the day during hot-syncs and therefore protection of the hot-synced data is crucial.[2] One proposed solution to this problem is to have clinical updates, as well as lab and pathology results, saved onto compact flash, secure digital or multimedia cards, or even via encrypted broadcast data systems (wireless networks), thus removing the hot-syncing.[2]

Institutions and companies are now addressing the technical challenges of connecting to disparate systems using mobile devices. Wireless networks are the likely medium for integration, but they also have unique security challenges. The most popular wireless technology called 802.11b (by techies) or Wi-Fi (short for Wireless Fidelity) allows multiple devices (PCs, PDAs, digital cameras, music players, and more) to share a high speed Internet connection over a distance of about 300 feet typically (although distances up to 5 miles have been attained).[33] They also can be configured to work similarly to a secure LAN (local area network), but security issues are still a major problem.[33] Software that "sniffs" for available networks is now included with most new mobile products.[33] Wireless Equivalency Privacy (WEP) is the basic encryption software in the field, but it is debatable if this will be enough security under HIPAA (highly unlikely).[33] Security issues aside, wireless networking capabilities in conjunction with mobile devices can reshape patient care.[34-36] The technology's potential is just being realized, as shown by the availability of data from patient monitoring systems to

practitioners at any time while on the move throughout a ward/hospital.[37] Doctors at Cedars-Sinai Medical Center have reported a successful trial of secure remote access to clinical data repositories using encrypted transmission and wireless PDAs.[38]

Messaging Integration with Legacy Systems:

In most cases, integration is still a major problem.[22,23] Mobile devices typically use a different logic for interactive use than traditional information systems.[9] They also tend to use Internet protocol and XML-based communication rather than traditional messaging found in many legacy systems.[9] Therefore, it becomes more complicated to integrate these modern mobile devices into legacy systems, which could increase the cost and negate one of the benefits of this technology.

Interference with Medical Devices:

Many believe there is still another far more dangerous issue with mobile health devices- the lack of standards on interference. In the past, some mobile devices have interfered with medical devices through low-level radiation.[39,40] Because of these reports, many hospitals have policies that prohibit the use of cell-phones and other wireless communication devices.[9] Obviously, more studies will be needed to determine just how careful we need to do be with mobile device and wireless networks in medical settings. The current general rule is that mobile devices should not be used within three feet of a medical device, but there are exceptions.[9] This would pose a problem and barrier to the goal of using mobile devices as tools for facilitating point-of-care practice.

An Implementation Attempt to Build Upon and Learn From

While there has been a lot of discussion about the major benefits and limitations of mobile technology use in clinical practice, there have been few full-scale development and implementation studies done. However, one study was recently presented at the 2002 American Medical Informatics Association (AMIA) Symposium that deserves detailed attention for its scope and importance to the field.[22] A.E. Carroll, S. Saluja and P. Tarcxy-Hornoch's 2001 project detailed the issues encountered when designing a client/server point-of-care addition for an already existing enterprise system.[23] It was previously believed that the ability to link data on a PDA (client) to a central database (server) allowed for near-unlimited potential in developing point-of-care applications and systems for patient data management.[23] The lessons learned from this project address the over-riding issues and limitations of PDAs as previously discussed. Carroll, et al., broke these limitations and issues down into four groups: PDA hardware limitations, software limitations, user issues, and necessary future advances needed for this technology to advance in a clinical setting.

Hardware Limitations:

Three major hardware limitations were encountered in the study:

1. The PDA screen size is too small for text-intensive portions of the medical record.
2. Text entry is still too difficult.
3. There is a fear of crashing.[22]

The size of the screen was inadequate for large textual documents and made it too time consuming for the clinicians to review the files.[22] Additionally, entering information into the system on a PDA required far too much time.[22] While PDAs are typically very stable,

they became quite unstable when pushed to their technical limits while running "relational-like" databases.[22]

Software Limitations:

Carroll, et al. encountered five major software limitations in their study:

1. It is very difficult and time consuming to alter database table structures.
2. Simple database software packages for PDAs are not suited for the large-scale data manipulation needed in most clinical settings.
3. It is difficult to maneuver between tables in the database.
4. Hotsyncing is asynchronous.
5. Data entry is effectively limited to either PDA or PC- not both.[22]

It became clear during the development phase of the project that they would not be able to integrate or emulate the enterprise system capabilities on the Palm® devices.[22] Therefore, they had to try and integrate the simple database software of the PDA to interact with and then transfer the information from the PDA to the enterprise system during hotsync operations.[22] This led to numerous problems as summarized above.[22]

User Issues:

As with all computer products, Carroll et al. could not fully predict what a user would do with their system once in use.[22] They summarized the user issues down to four main categories:

1. Some things must still be done with pen and paper.
2. Users require some data to be stored in ways not easily accomplished on PDAs.
3. If the system is not fulfilling a need, users will do something else on their own. They cannot be forced to use the system.
4. Users have vastly different needs with respect to both the EMR and PDAs.[22]

While pen and paper is still the desired technique for some tasks (at least when the other option is PDA input), it is possible that future advances and products in digital pen and paper technology, such as the Logitech® io Personal Digital Pen, could fill this gap.[41,42]

This study by Carroll, et al. makes it clear that usability studies of mobile healthcare devices are necessary.

Improvements for success:

While Carroll et al.'s PDA based client/server patient record and charting system had very limited success upon implementation, it clearly identified a number of areas where handheld hardware and software needs improvement for mobile devices to succeed in clinical settings.[22] They recommended four improvements,

1. More sophisticated database applications are needed with easy linking to enterprise systems.
2. Synchronous data transfer without sacrificing security is desired (e.g. wireless networks).
3. Easier data entry, perhaps with voice recognition and dictation, is needed.
4. Increased screen size is required.[22]

The database problem could be quite complicated due to the multitude of enterprise clinical systems currently in use in the marketplace. Due to the PDA's relatively low computing power, the enterprise system could not be given a Palm® interface. Therefore, a Palm®-based database had to be used and the option of using a wireless network to access the enterprise system was not feasible. It is likely that handheld interfaces will be developed in the future for each system on the market, but they require integration with the development kits of the original systems and will require much time, effort, and cooperation by vendors to succeed. The need for connectivity through wireless networks was earlier discussed, with the point again being that the network is not a powerful tool if the systems can't take advantage of synchronous data transfer (i.e. they must speak the same language). The difficulties of data entry do not offer a simple solution either. Voice recognition and dictation is at the mercy of the quality of technology, which is rapidly improving but not yet up to the standard necessary for the medical field. As

mentioned previously in the user issues on data entry, note capture devices, such as digital pen and paper and tablet computers, are still being developed and cost/quality is quite a concern.[42] Finally, increased screen size can be solved, but will take away from the "size of the palm" aspect of the device. Also, it would seem wise that if the size were increased, then computing power should also be increased (in a sense creating a mini-laptop computer).

Future Solutions using Next-Generation Devices?

In the end, some of these limitations can easily be solved while others are a function of the technology/medium at hand, and therefore a next generation device is likely to fill the need. The ultimate goal is to enable mobile access to electronic medical records, lab results and charge applications.[16] To do all these tasks, hand-held pen tablet computers ("tablet PCs") may play a key role.[16]

Tablet computers are basically laptop computers that utilize a touch screen to gather input instead of a keyboard and mouse (although those can be connected if desired). The very few early studies that have been done with tablet computers have shown usability limitations, although most are dated.[43-45] As HIPAA goes into effect and the health care industry begins to invest more in information technology systems, the growth of tablet computers could follow that of the Palm® Pilot.[46] Time will tell if the tablet computer will meet the demand or if work around solutions will be developed to allow the PDA to be the all-purpose tool in this setting. It is also quite possible that both may take specialized footholds in the market, and be used in combination with other up and coming technologies such as digital pen and paper applications. However, like all

new technologies, the usability of the tool in the field, rather than its computational prowess, will likely determine the success of tablet computers in healthcare settings.

A Pilot Study of Usability Analysis of Wireless Tablet Computing in an Academic Emergency Department Setting

Introduction

Technical journals in every specialty of the medical field, from nursing to ambulatory health care to general practice physicians propose that mobile computing will help to finally realize the benefits that health care information technology has been promising for years.[47-50] While not all workers will suit a mobile computing device and not all mobile computing devices, if any, will suit a particular worker, it is clear that when a mobile computing device is used within its limitations it can be a powerful tool in clinical practice. It is likely that in the coming years physicians will be able to perform many of their information management responsibilities from individual mobile devices that are with them at all times during their shifts, making point-of-care computing a reality. From accessing reference materials in order to better practice evidence-based medicine, to recording patient visit notes in the electronic medical record, to ordering tests and e-prescribing, mobile computing devices connected to clinical systems will soon enable medical professionals to improve their productivity and, more importantly, patient care. While technical issues may be part of the decision to use a tool, more importantly usability issues may ultimately determine which mobile device is of the most value in a particular healthcare setting. This pilot study examines usability testing of a tablet computer in an academic emergency department.

The Need for Usability Testing

While it is recognized that decisions on the introduction of hand-held computers and other technology into clinical practice should not be made by IT departments alone, but rather after thorough discussion with the staff that will be expected to use them, usability studies are rarely performed in clinical information technology.[51] Medical professionals have a very pragmatic way of determining usability in the field; if a tool meets their needs they use it, otherwise they abandon the tool and quickly find another way to get the job done. This likely is due to the yes/no process of decision making due to time limitations and medical decision making training. Computers should aid the work to be done, not hinder it.[52] Usability studies can allow for the pre-evaluation and testing of tools prior to full scale implementation. Such studies can be quite valuable in sculpting the tool for a job rather than trying to find a job for the tool; thereby, reducing the chance of implementation failure. Early marketing of the tablet computer to healthcare seems to follow more of a job-hunt for the tool.[53]

Usability testing is an important part of the software development cycle that addresses user interface design. However, not all usability testing is done during initial product development. Kushniruk et al. advocated for usability analysis to study actual behavior, proposing an iterative design process that included end product testing.[54] They pointed out the need for developing and applying methodologies for accurately assessing usability of user interfaces in medical informatics. They also postulated that the conventional methods of evaluation through questionnaires and interviews may be limited to providing recall information and not truly represent actual user interface interaction.

Aborg et al. focused on evaluating the usability of information systems used by professionals on the job.[55] They wanted to address issues that could lead to poor performance, low user acceptance and inefficient work procedures. In a 1997 study of "real world" application of these proposals, Coble et al. described usability testing of a clinical workstation.[56] They found that the most effective measurement of a function's usability was the number of problems that physicians encountered during a given task. Their methodology included gathering background information, creating usability tasks, testing, analyzing the results and determining problems, making appropriate changes in the workstation, and repeating the cycle until problems were reduced to an acceptable level. It was concluded that usability testing increased the likelihood of success in "real world" usage of the clinical workstation.

In software development, anything that prevents a user from using a product to his/her satisfaction can be considered a barrier.[57] Similarly, in the workplace, any tool that prevents or slows down a user from completing a task is a barrier. Some barriers are user specific, but many are tool specific. Having knowledge of the various tool-specific barriers prior to full-scale use enables information technologists to sculpt the tool for the job, rather than the tool sculpting the user. This capstone project studies usability analysis to determine benefits and limitations of wireless tablet computing in a health care setting.

The Emergency Department at Oregon Health & Science University

The Oregon Health and Science University (OHSU) Emergency Department (ED) is an urban university-based tertiary care emergency department and a level one trauma center that sees 46,000 patient visits a year. The Emergency Department has 40 patient

care rooms, including a ten-bed observation unit, a dedicated pediatric emergency department and a minor care treatment area.

The ED is interested in exploring bedside registration and point of care documentation, but the optimal hardware setup for this task has yet to be determined. The OHSU ED currently uses the EmSTAT computerized patient information system software suite, and therefore any solution should be compatible with EmSTAT.[58] There are three main computer setups that the OHSU ED envisions to meet this goal: wired desktop computers in every patient care room, wireless mobile laptop workstations, or wireless handheld computers. Wired desktop computers are currently interspersed throughout the department in high traffic areas for use by nurses, attendings and residents. Attendings and residents also have a separate computer room available to them, but it is in the corner of the ED and not along traffic corridors. Additionally, a wireless 802.11g network has been deployed throughout the ED for experimental use. Currently, a few rolling laptop computer workstations connected to the wireless network are available for use by nurses during admittance.

Additional wired computers could fill this need, but they are expensive and consume space in already tight patient care rooms.[59] Additionally, medical staff have expressed a preference for more mobile solutions to better match their mobile workflow. Due to the limited use and success of the mobile laptop PCs currently in the department, the ED would like to explore the use of handheld computers. However, in lieu of the lessons learned from Carroll et al.'s earlier discussed implementation attempt, it is clear that PDAs do not currently have the processing power or storage abilities to handle the end-user requirements that the current software applications in use by the ED put on the

client. The only mobile technology currently on the market that could handle the software requirements of the ED is the tablet computer. Therefore, a pilot usability study with tablet computers was done to evaluate the possibility of using such a tool in the OHSU ED.

Goals of the Project

1. Determine an economical and efficient method of analyzing the usability of a tablet computer in the Emergency Department.
2. Demonstrate the effectiveness of the method by performing a pilot-study usability analysis to determine basic benefits and limitations of using the tablet computer in the OHSU Emergency Department.

Usability Testing

The What and Why of Usability

According to the International Standards Organization (ISO), usability is "the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments."[60] Nielson differentiates usability from usefulness and utility by stating that usability relates to the user; more specifically, if the user can interact efficiently with a system through its user interface.[61] In other words, usability is directly connected with efficiency. The cost of determining usability should outweigh the potential waste of providing resources that are not optimally used.[57] In many cases, it is possible to do an economical and efficient analysis of usability to quickly determine basic information for use in preparing for larger scale studies. Usability testing has been

shown to provide cost savings regardless of the industry or tool. However, performing a large-scale usability study when only an economical and efficient approach is necessary would be wasteful and inefficient.[61]

Overview on the Methodologies of Usability Testing

There are numerous measures of usability. These include measuring user performance during interaction with the system and user attitude towards the system. User performance includes ease of use, which can be measured by the time it takes to complete a task, the number of user mistakes, and the learning curve. In many cases, user attitude can skew the acceptance of a product or tool and therefore it is the most important measurement in usability. Even if a user is productive, if the feeling is of dissatisfaction then a user can be inefficient with a tool; therefore, if one were to express usability as an equation:

Satisfaction + Efficiency= Usability.

In response to dissatisfaction with usability, work and behavior can be unexpectedly modified and lead to damaging results. Therefore, from an organizational behavior standpoint, fully understanding the usability of technical tools is vital to successful implementation. Usability studies help to measure and determine if what is good for some settings may not be good for others.

As with measures of usability, there are also numerous methodologies of usability testing. A quick overview of the major techniques follows.[62]

- **Heuristic evaluation** is the most informal method and involves having usability specialists' judge whether each dialogue element follows established usability principles (the "heuristics").

- **Heuristic estimation** is a variant in which the inspectors are asked to estimate the relative usability of two (or more) designs in quantitative terms (typically expected user performance).

- **Cognitive walkthrough** uses a more explicitly detailed procedure to simulate a user's problem-solving process at each step through the dialogue, checking if the simulated user's goals and memory content can be assumed to lead to the next correct action.

- **Pluralistic walkthrough** uses group meetings where users, developers, and human factors specialists step through a scenario, discussing each dialogue element.

- **Feature inspection** lists sequences of features used to accomplish typical tasks, checks for long sequences, cumbersome steps, steps that would not be natural for users to try, and steps that require extensive knowledge/experience in order to assess a proposed feature set.

- **Consistency inspection** has designers who represent multiple other projects inspect an interface to see whether it does things in the same way as their own designs.

- **Standards inspection** has an expert on an interface standard inspect the interface for compliance.

- **Formal usability inspection** combines individual and group inspections in a six-step procedure with strictly defined roles, with elements of both heuristic evaluation and a simplified form of cognitive walkthroughs.

Heuristic evaluation, heuristic estimation, cognitive walkthrough, feature inspection, and standards inspection normally have the interface inspected by a single evaluator at a time.[62] However, heuristic evaluation is based on combining inspection reports from a set of independent evaluators to form the list of usability problems, and heuristic estimation involves computing the mean of the individual estimates.[62] In contrast to single evaluators at a time, pluralistic walkthrough and consistency inspection are group inspection methods.[62]

Discount Usability Testing

Many usability methods are found to be intimidating, too expensive, and too difficult and time consuming to use. The "discount usability engineering" technique proposed by Nielson can be modified to overcome these problems and work in the emergency department environment. In fact, deluxe user testing employs a larger number of users at greater cost with no greater benefit (FIG. 1).

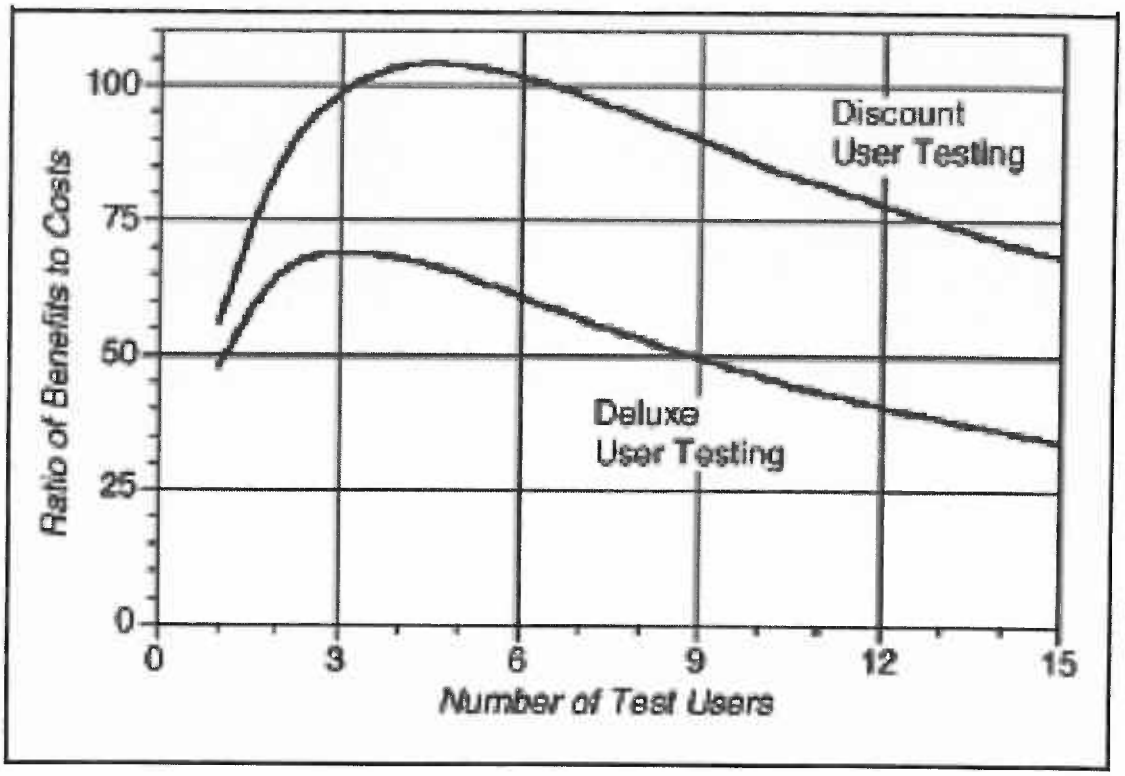

Figure 1. Discount User Testing Versus Deluxe User Testing
Nielson and Landauer (63). The curve depicts the ratio between the benefits of user testing and the costs for medium size development projects. The curves show that the benefits are greater than the costs no matter how many subjects are used. 3-5 subjects achieve the maximum cost/benefit ratio.

Nielson's discount technique is a combination of three techniques: scenarios, thinking aloud, and heuristic evaluation. Scenarios examine only part of system or tool, allowing for quick and frequent feedback from users. In think aloud sessions, users' voice out their thoughts as they perform tasks using the system or tool. Heuristic evaluation involves having a small set of evaluators examine the interface and judge its compliance with recognized usability principles (accepted guidelines known as the "heuristics"). Heuristic evaluations are not typically expected to address all usability issues, as they are commonly conducted during the development process of a product by evaluators that have little to no knowledge of the actual end-users and their tasks

(FIG. 2). The evaluators in Nielsen's approach, while experts in their fields of software engineering and usability or human factors engineering, are not expert users in every setting in which the tool may be used. Muller et al. thought about this dilemma and extended the list of possible experts to include work-domain experts (in other words, users) because they are experts in their field of work and how the tool or system ultimately will be used (the true "heuristics on the job").[64] Among the methods discussed, heuristic evaluation and user testing have been determined to be the most useful, depending on the setting.[65]

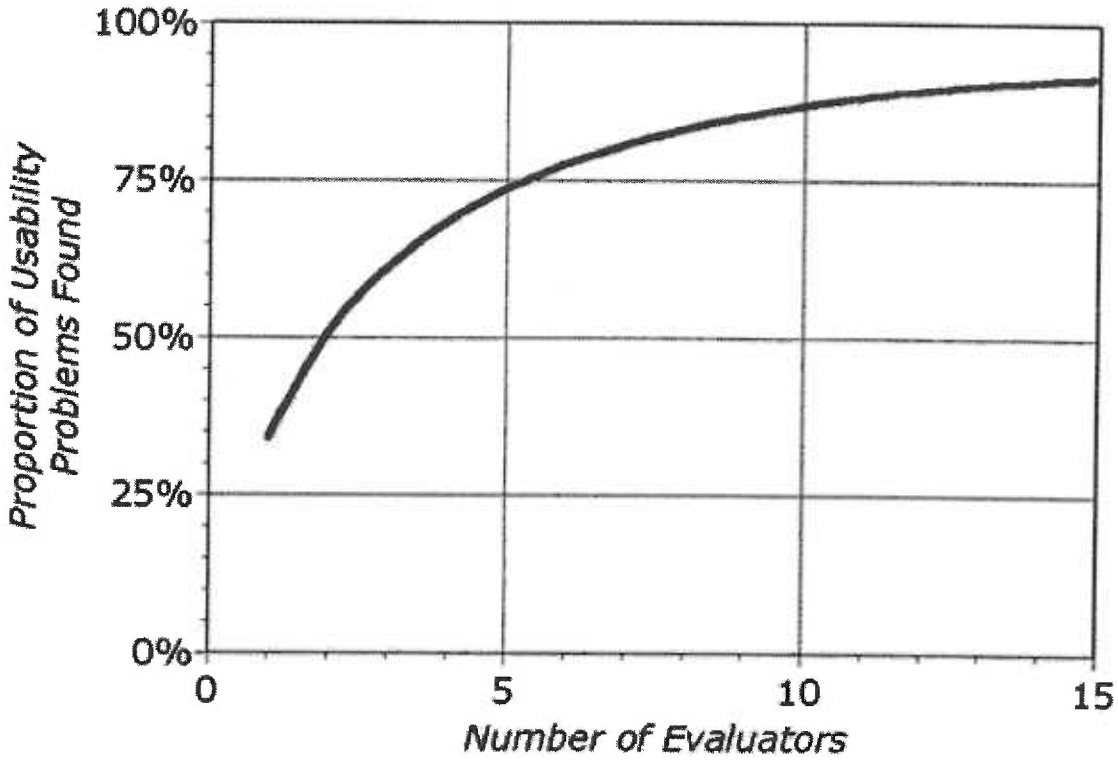

Figure 2. Usability Issues Found

Nielson and Landauer (63). The curve depicts proportion of usability problems in an interface found by heuristic evaluation using various numbers of evaluators. The curve depicts the average of six case studies examined. Again, 3-5 evaluators achieve the maximum cost/benefit ratio (like the user testers of Fig.1), setting a foundation for the optimal number of subjects in a discount usability analysis.

As scenarios simplify the situation and medical professionals have a distinct way of determining usability in the field, it was decided that scenario testing was more realistic if done in "real-life" situations versus simulations. Additionally, the author concluded that heuristic evaluation from outside the medical professions would offer little to no value compared to user testing heuristic evaluation. It was decided to use both residents (true "users") and attendings ("experts" in their field) in the user testing heuristic evaluation. Residents are physicians who care for hospitalized patients under the supervision of the medical staff, namely attending physicians. Attending physicians ("attendings") are supervisory physicians. Finally, it was decided that think aloud sessions could be incorporated into the user testing as well to get the most "real life" situation as possible. Taking discount usability testing and exposing it to real world situations allows for the maximum determination of limitations that can be identified before an expensive deployment of a technological tool.

Methodology

Overview

A modified discount usability testing method was undertaken for this study. The methodology was approved by the Institutional Review Board (IRB) at OHSU under IRB #7802. The evaluation consisted of four main phases: pre-evaluation training, evaluation, debriefing, and severity rating using a survey. The pre-evaluation training phase allowed for basic training on tablet computer operation. In the evaluation phase, users were given the tablet computer and asked to use the tool in a manner in which they would normally use a computer on the job and in any new ways they saw fit. Users were also asked to

voice out their thoughts as they used the tablet. During debriefing, comments made during the evaluation session were discussed. The users were also asked to provide any comments on potential improvements for using the tablet computer in the ED. A severity survey was then generated based on the evaluation and debriefing information. The users were then asked to complete the survey to finish the testing.

Selection of Subjects

A convenience sample of attending and resident physicians was selected to participate in the study. Nielsen and Landauer derived a mathematical model for expected cost/benefit ratios based on the number of users, as depicted in Figure 3. With 3-5 users producing the optimal cost/benefit ratio, as also shown in Figures 1 and 2, the author selected within that number for the study. As resident computer use and job tasks differ somewhat from attendings, three to five users of both residents and attendings were selected. In the end, the usability test consisted of five residents and four attendings.

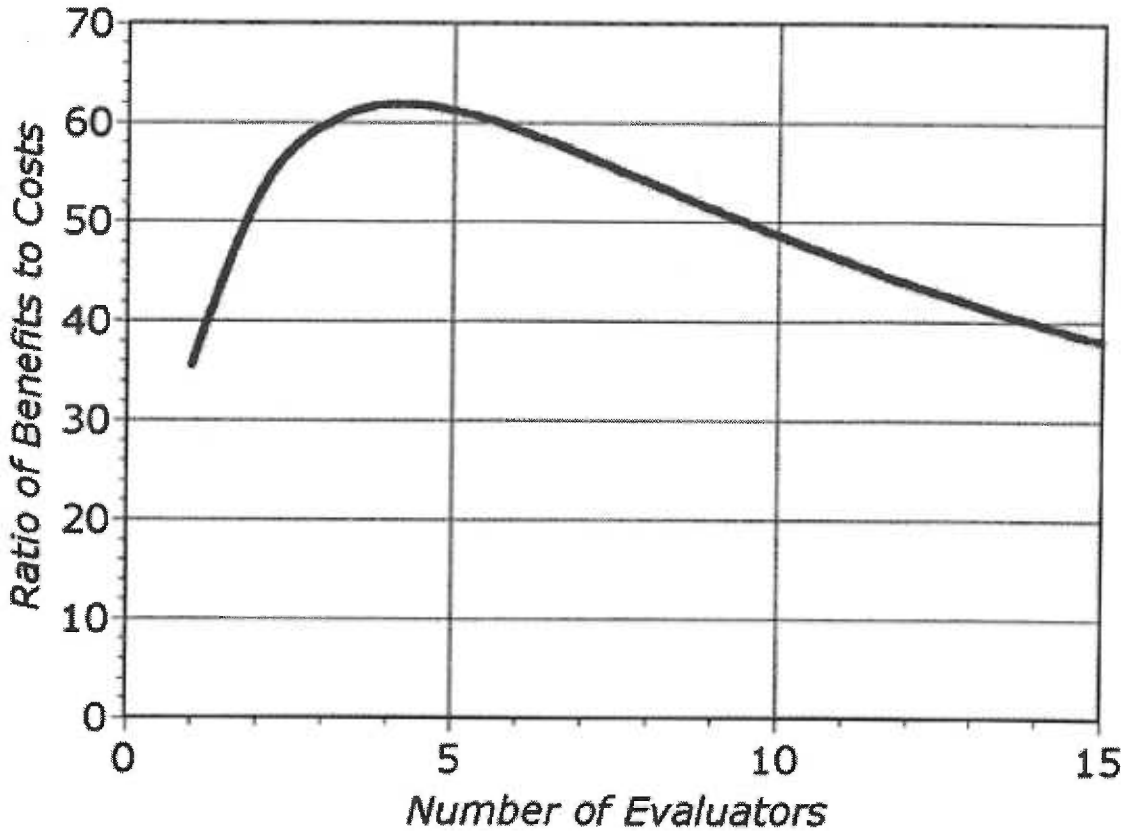

Figure 3. Cost/Benefit Analysis of Discount Usability Engineering
Nielson and Landauer (63). The curve depicts expected cost/benefit ratio using various numbers of evaluators in a heuristic evaluation. The curve depicts the average of six case studies examined.

Tablet Computer Specifications

The tablet computer used in the study was a Viewsonic Viewpad® 1000, running Microsoft Windows® 2000 Professional Edition (FIG. 4, Table 1).[66] The client of A[4]Health Systems® EmSTAT v. 7.9 was loaded on the machine and full intranet and internet use was available on the machine via the wireless network.[58]

Figure 4. Viewsonic Viewpad® 1000 Tablet Computer

Processor	Mobile Intel® Celeron® processor 800MHz
Operating System	Microsoft Windows® 2000 Professional Operating System
Memory	128 MB (SDRAM, 512MB max expansion)
Hard Disk Drive	10.0GB
Display	Resistive screen/ 10.4" 800-by-600 rotatable TFT LCD
Dimensions (HWD)	12.2" x 8.9" x 1.4"
Weight	4.3lbs (7.2 lbs with keyboard, slip case, and transformer)
Battery	5,400-mAh (~4 hours of use claimed)

Table 1. Viewsonic Viewpad® 1000 Tablet Computer Specifications

Pre-evaluation Phase

The pre-evaluation phase first involved orienting the study proctor [C.A.] with normal procedures and computer use in the ED at OHSU. After becoming oriented with the work environment, the author conducted basic tablet computer training for the user-

evaluators. The training consisted mainly of pointing out that the users had the machine to themselves and that the tablet had touch screen input versus mouse or keyboard driven input. An area on a centrally-located open counter in the ED was also made available to the users where they could plug the tablet in for charging the battery and/or using a wireless keyboard for input instead of using the touch screen keyboard on the screen. The users could ask the author at any time during the evaluation for help on how to use the machine.

The desktop machines in the ED were running Windows® 2000, in contrast with the tablet-modified Windows® 2000 version on the tablet. However, changes between the operating systems are minor to the basic end user. After exploring the digital handwriting recognition options on the tablet, it was decided that it was too specialized of an option to include in the discount usability study. Handwriting recognition software on the machine worked best after the user had trained the machine to better recognize his or her unique handwriting. With only one machine available for the study, it would have been unrealistic to include this functionality.

Evaluation Phase

For the evaluation phase, each subject conducted his or her user test evaluation individually and independently of the other subjects for part of a typical work shift (~3 hours, depending on how busy it was in the ED). They were asked to explicitly identify each problem and benefit to the study proctor, who made a note of each for further analysis. The goal was to make basic notes at the time of the problem or benefit to supplement and clarify the topics for discussion in the debriefing sessions. It has been

shown in previous usability studies that finding usability problems and the more detailed analysis of such problems are two distinct processes that should not be interleaved in a single session.[62] Therefore, instead of elicitation of severity classifications during the evaluation session, information about the severity of the usability issues will be gained during the debriefing and survey phases.

Debriefing Phase

The principle purpose of the debriefing sessions was to discuss the general characteristics of the tablet computer interface as well as speculate on potential improvements to address some of the major usability problems that were found. The debriefing sessions occurred immediately following the evaluation sessions. Comments made by the subjects during the evaluation phase were discussed further, along with general characteristics of the tablet interface.

Survey Phase

In an effort to further clarify and pinpoint the major usability issues, the subjects were asked to rate in severity the usability issues discovered in the study, allowing for a quantifiable end result to augment the qualitative information from the evaluations and debriefings. Comments collected from field notes during the evaluations and from the debriefing sessions were organized into common themes. The common themes were used to create a severity survey that would solicit hypothesis-generating qualitative and quantitative feedback to further define the usability of the tablet in the ED.

The severity scale in the survey used a Likert scale, which measures the extent to which a person agrees or disagrees with a question. For the questions about tablet computer usability gained from the evaluations and debriefings, the Likert scale was adjusted to be the following: 1= this is a major problem, 2= this is a problem, 3= not sure if this is a problem or a benefit, 4= this is a benefit, 5= this is a major benefit. Additionally, one question would be asked about the user's comfort with computer technology, and the Likert scale was adjusted to 1= really not comfortable, 2= not comfortable, 3= somewhat comfortable, 4= comfortable, 5= very comfortable.

Results

Evaluation and Debriefing

Evaluation of field notes revealed some common themes. It was clear during the evaluation phase that the tablet was used mainly as a mobile screen to see what is going on in the ED. EmSTAT has a major function in which a virtual whiteboard is instantaneously updated with information of all the patients and their complaints, room assignments, etc. The users appreciated having the ability to view this billboard while in the patient rooms and on the go, versus having to continually walk over to an unused computer to see the screen. The users also seemed to really like the fact that it was their machine to use. That meant that they did not have hunt for computers and log in and out of them all shift to do their job. The users seemed to dislike the heavy weight and had mixed opinions about the large size of the tablet. They also found the data input options to be limiting, reliability to be unacceptable, and had mixed views as to whether access to patient information in the examination room was useful. Finally, they were unsure what to do with the tablet when not in use since they were concerned about security, damaging

the device, and/or leaving it behind somewhere. One recommendation was to use a messenger bag and place the tablet into the bag when you not in use.

Survey

From the major themes determined from the evaluation and debriefing stages, a twelve question survey was generated. The survey broke down into the following: nine questions directly related to usability, one question regarding comfort with technology, one question to differentiate residents from attendings, and one open-ended question asking for final comments about their experience with the tablet computer. The survey was generated using the online survey tool Survey Monkey.[67] The first ten questions appear in Table 2. The two additional questions follow:

Resident/Attending differentiation question:

11. Are you a resident?

Open-ended final comment question:

12. Do you have any final comments you would like to make about your experience with the tablet computer?

Eight of the nine subjects completed the survey. One attending abstained due to multiple technical malfunctions during the evaluation session which limited the use of the tablet to less than an hour. With three attendings still being enough for a maximal cost/benefit ratio, it was decided not to reschedule the evaluation. The results of the survey are depicted in Table 2 and Figure 5.

Survey Question	Attendings n=3	Residents n=5
1= this is a major problem, 2= this is a problem, 3= not sure if this is a problem or a benefit, 4= this is a benefit, 5= this is a major benefit.		
1. What did you think of the ability to be mobile with a computer during your shift in the ED?	3.67	4.20
2. What did you think of the touch screen on the tablet versus using a normal mouse?	3.33	4.00
3. What did you think of the Virtual Keyboard on the tablet screen versus using a normal keyboard?	1.67	3.00
4. What did you think of the tablet screen size versus a handheld (Palm® Pilot or the like)?	4.00	3.80
5. What did you think of the weight of the tablet?	1.33	2.20
6. What did you think of the reliability of the tablet to do your needed computer tasks?	2.00	3.80
7. What did you think of the ability to have your own computer to use during your shift versus using the current shared desktop arrangement?	3.33	4.60
8. What did you think of the ability to go through a patient's previous medical history (by reviewing the records on the tablet) with the patient in the examination room?	4.00	4.00
9. What do you think of using a carrying bag/shoulder holder for the tablet instead of having to carry it and find a place to put it down when you need to use your hands?	3.30	3.20
1= really not comfortable, 2= not comfortable, 3= somewhat comfortable, 4= comfortable, 5= very comfortable		
10. How would you rate your comfort with computer technology?	4.67	4.00

Table 2. Survey Results
Average Likert scores for the attendings and residents for each survey question.

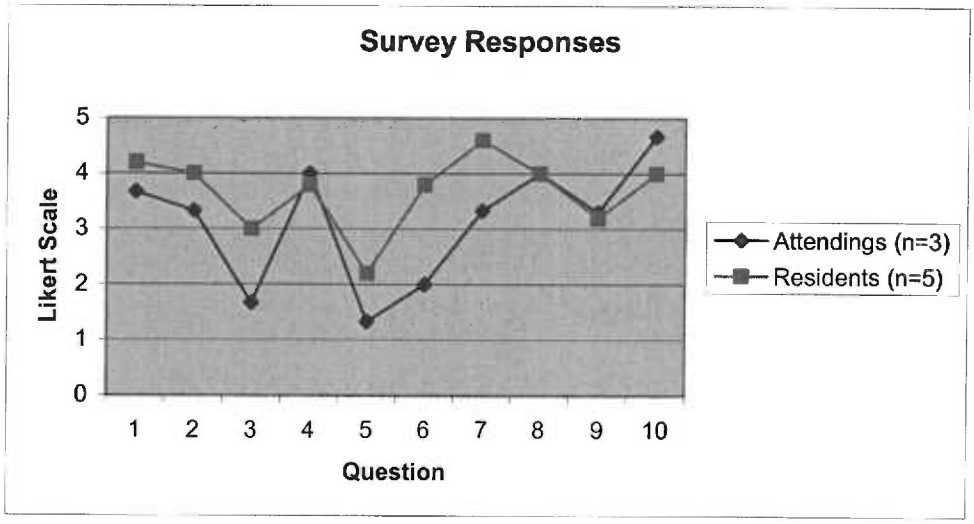

Figure 5. Survey Results
Average Likert scores for the attendings and residents for each survey question.

The results of the open-ended final question offered more insight into some common themes.

Theme 1: The Tablet PC's form factor is not correct.

"The current version is too heavy and fragile for general use in the ED."

"The size, weight, [and intermittent reliability issues] made this something that I don't think I would use in its current form. The need to make something small enough to fit in a coat pocket is key. I think PDA development, possibly with a larger screen and easier keyboard to use, would be the way to further develop this."

"The keyboard function was poor and may be improved by using a Windows® Tablet XP tablet. A little heavy, but not too bad."

"Cumbersome and slow to use at the bedside for entering notes with a keyboard."

"A great idea, but too heavy, and difficult to find a place to set it down when not actively being used. Palm®-Pilot size would be the ideal toward which to strive."

"Portability is the major issue—where is a safe place to put it when I'm in a room, how about in a crowded code situation? I think touch screen and free writing pad will be better than computer keyboard (except for #s)."

Theme 2: The Tablet PC is too unreliable.

"The tablet worked well when it worked, but it had frequent technical issues."

"The [size, weight, and] intermittent reliability issues made this something that I don't think I would use in its current form."

"The tablet worked well when it worked, but it had frequent technical issues."

Theme 3: The Tablet PC's niche is unclear.

"I think the tablet needs to find its proper niche into emergency operations."

Theme 4: The Tablet PC's interaction with healthcare information system software is crucial.

"I think what should be stressed is the feature set (i.e. ability to see the chart while in the room) not the form factor."

"Mouse click or touch click check boxes are the only way this will help speed data entry in a user-friendly way- i.e. T-chart."

"The tablet computer would be much more beneficial from a usability standpoint if orders could be placed and lab results could be accessed directly from EmSTAT, instead of bouncing back and forth between the Clinical Data Repository and EmSTAT. Even better would be the ability to keep a separate log of your own patients and all data pertinent to them . . . but this is probably asking too much . . ."

Discussion

Usability Survey in Review

The overall average Likert score by residents and attendings for the usability questions on the survey was 3.3. Residents' average score was 3.68, and attendings' average score was 2.92. Taken as an overall view of the tablet computer, this showed that both groups were equally unsure of whether or not it was a beneficial tool. However, when analyzing the scores for each question along with differences between the scores for each group, more details are exposed.

Question 1	**Attendings**	**Residents**
What did you think of the ability to be mobile with a computer during your shift in the ED?	3.67	4.20

Question 1 addressed computer mobility, and it was not surprising that both groups seemed to think it was beneficial. The residents in particular found it to be quite beneficial, and this follows their work situation in which they are on the move more than attendings.

Question 2	**Attendings**	**Residents**
What did you think of the touch screen on the tablet versus using a normal mouse?	3.33	4.00

Question 2 addressed the touch screen function, of which the residents again found to be beneficial, while the attendings had mixed feelings. This could possibly be age related due to comfort with mouse driven input versus interest in exploring new technologies. Unfortunately, background information such as age was not collected.

Question 3	Attendings	Residents
What did you think of the Virtual Keyboard on the tablet screen versus using a normal keyboard?	1.67	3.00

Question 3 addressed the touch-screen virtual keyboard. The difference between groups appeared large in this case, with the residents mixed in their feelings, while the attendings clearly thought this was a problem (in line with their feelings toward touch screen input in question 2).

Question 4	Attendings	Residents
What did you think of the tablet screen size versus a handheld (Palm® Pilot or the like)?	4.00	3.80

Question 5	Attendings	Residents
What did you think of the weight of the tablet?	1.33	2.20

Question 4 addressed the tablet's size, and both groups clearly thought that the larger screen size was a benefit when compared to the small screens of PDAs and the like. However, the size came at a cost, which was reflected in question 5 where both groups clearly felt that the weight was an unacceptable problem.

Question 6	Attendings	Residents
What did you think of the reliability of the tablet to do your needed computer tasks?	2.00	3.80

Question 6 showed that there may be a difference between the groups regarding their views about the reliability of the tablet. Throughout the evaluation period multiple technological issues caused the tablet to crash or not work properly. In particular, the sessions with the attendings had more problems than the resident sessions. One possible

explanation of this discrepancy is that maybe the residents were a little more understanding and accepting of the technical problems.

Question 7	Attendings	Residents
What did you think of the ability to have your own computer to use during your shift versus using the current shared desktop arrangement?	3.33	4.60

Question 7 was quite informative in that it provided insight into a larger workflow issue of the ED. The question had to do with the fact that the tablet computer was not shared during the shift. One resident was overheard numerous times saying, "This is mine." Numerous residents spoke out about the fact that nurses huddling around the computers made the shared computer situation difficult. Also, the fact that the residents are required to input the most information about the patients into the system meant that they regularly needed access to computers. However, due to the nature of the job, they rarely had time to do it all in one session, which meant that they continually had to log on and off of machines. With their own computer, however they could remain logged into one machine for the whole shift if desired. The work of attendings was in many cases more advising and teaching, with less paperwork, patient visits, and data input. Therefore, their need for having their own personal computer seemed to be less than that of residents.

Question 8	Attendings	Residents
What did you think of the ability to go through a patient's previous medical history (by reviewing the records on the tablet) with the patient in the examination room?	4.00	4.00

Question 8 discussed one of the most touted features in the literature of mobile computing in healthcare- access to patient records in the examination room. Both groups equally agreed that having this ability this was a benefit, although they were not all convinced that the tablet form factor was the best solution.

Question 9	Attendings	Residents
What do you think of using a carrying bag/shoulder holder for the tablet instead of having to carry it and find a place to put it down when you need to use your hands?	3.30	3.20

Question 9 discussed one of the limitations to having your own computer. What do you do with it when you need your hands or do not otherwise need to use it? There are security concerns of being logged into the system and placing the machine where someone can steal it or use it without authorization. During the evaluation, one attending thought a solution would be to have a carrying case, and so question 9 proposes such. The view was universal in that both groups were unsure if this was a benefit or a problem, so it bears further study.

Question 10	Attendings	Residents
How would you rate your comfort with computer technology?	4.67	4.00

Finally, question 10 addressed perceived comfort with computer technology to see if there were associations between comfort and usability feelings for the tablet and its features. Both groups rated themselves highly, particularly the attendings, so bias related

to being uncomfortable with technology was not a major factor. If anything, all the subjects were so comfortable with technology that they had little patience for anything that did not work the first time, as they've come to expect and rely upon computers to efficiently do their job.

Open-Ended Comments in Review

The open-ended comment section of the survey provided some interesting insight into what issues were of most concern to the individuals, which a Likert scale survey could not pick up on its own. Most of the comments followed along with particular topics covered in the survey, but a few brought up the larger issues involving tablet computing in healthcare- bedside computing and physician order entry.

In the current usability study, the system in use on the desktop computers of the ED was transferred to the mobile tablet computer. There was no differentiation or changes made to the software system to enable it work better with mobile touch screen technologies. As noted in the comments, many of the problems with the form factor had to do with its integration with the software and with the software setup in general. For example, the software in use requires multiple logins between programs and quite a bit of keyboard input. Mouse-click saved logins, order sets and check boxes could likely speed data entry and take advantage of the touch screen feature.

The ED at OHSU is still mostly a paper-based department, so having to deal with both paper and computer files located in multiple systems only further complicates the matter. The ED has implemented electronic prescribing, but other CPOE functions are limited. Only previous OHSU patients are entered in the OHSU clinical data repository

(CDR). The rest of the patients have paper files generated upon check-in. For those patients in the CDR system, the evaluators found it beneficial to have bedside access to the records to confirm and discuss a patient's previous ailments. Unfortunately, having to log in to separate CDR and EmSTAT modules that did not communicate with one another was frustrating to the evaluators. If an electronic medical record system were completely in operation and integrated with EmSTAT, the tablet could likely become a much more valuable tool, whereas in the current state it would be more of a novelty. In fact, in the current set-up of the ED, mobile technologies may actually slow down workflow due to software that is not designed for the mobile worker.

Even in this basic study, it is clear that the needs of a mobile system differ from those of desktop-based systems. In fact, Ying argues that a new category of computerized physician order entry (CPOE) should be established called MPOE, Mobile Physician Order Entry.[68] MPOE would be different from CPOE in form, function and implementation. In this study, the only MPOE change from the partial CPOE system in the ED was the form of the computer. Function and implementation differences were not considered. But, the comments reflected that function and implementation clearly need to be addressed before this can be a viable tool. Ying advocates further by writing, "With industry emphasis on mobility and error reduction only beginning to intensify, MPOE will become indispensable as both a stand-alone solution and a complementary system in hospitals' order entry strategies."[68]

Tablet Computer Limitations

As previously mentioned, the PDA implementation attempt by Carroll, et al. discussed hardware, software, and user limitations along with some improvements for success. This tablet study showed that the tablet computer addresses some of these issues. However, other unaddressed issues seem to be less specific to the form factor and more general to mobile technologies versus desktop systems.

Technical problems arose during many of the evaluations. Initially, the wireless network had problems. Then, the network interface card on the tablet failed. Finally, once all the hardware problems were solved, it became clear that the client load that EmSTAT put on the tablet was more than it could handle. EmSTAT is a very powerful network intensive software suite. In the end, without being able to pinpoint the exact cause, a best guess is that it likely had to do with the difference between the operating system of the tablet (Windows® Tablet 2000) and the rest of the machines on the network (Windows® 2000). The tablet machine was the older version of what is now available on the market, in that it did not run the Microsoft Windows® Tablet XP operating system. The latest version of EmSTAT that was in operation in the ED had drivers for Windows® 2000 loaded on all the machines. Thus, the EmSTAT client that was loaded on the tablet had Windows® 2000 drivers as well. Windows® 2000 drivers that were compatible with tablet-modified Windows® 2000 and the EmSTAT version used in the ED were not obtainable. However, even with the multitude of technical breakdowns, the tablet computer was operational for most of the evaluation sessions, with fits and breaks at times during the sessions.

The hardware limitations of screen size, difficult text entry and the fear of crashing in the PDA implementation attempt by Carroll, et al. were still present with the tablet computer. The users liked the size of the screen, but did not like the associated weight that went along with it. Text entry was still difficult with the tablet, although handwriting recognition was not included in the study and may help in attending to this limitation. The fear of crashing was ever-present in this study, although for different reasons than the PDA implementation attempt. In this study, as previously discussed, the crashing was most likely due to operating system differences and not due to the limited processing and storage space on the device. In effect, the crashing solution for the tablet is likely to be much simpler than for the PDA because it likely only involves upgrading operating systems versus redesigning and integrating software.

The goal of the tablet being able to completely solve the problems found in the implementation attempt by Carroll, et al. of PDA software integration due to hardware limitations was not reached during this study. However, most of the other software limitations discussed in Carroll, et al. were solved by running the tablet as just another client on the network (albeit a wireless one). Solving the user issues was another story though. As with the PDA, even when using a tablet computer, some things must still be done with pen and paper due to the fact that the workflow in the department is not entirely electronic. The users still desired to store some data in ways not easily accomplished with a network based shared system. This, however, seems to be a problem with the software system and the electronic medium as a whole, and not isolated to the tablet computer. The other two big user issues discussed in Carroll, et al. were not resolved using the tablet computer instead of a PDA. Users still could not be forced to

use the tablet, and therefore used something else when it did not fulfill their need. Users did desire to use electronic medical records in more functionality with the tablet, but were limited by the lack of full scale EMR and CPOE implementation.

As for the improvements for success discussed in Carroll, et al., two were met and two still require future advances for tablets to be successful in healthcare. Synchronous data transfer was readily available on the secure wireless network. The data did not require conversion due to the fact that the same software package was running on the tablet client as found on the desktop clients. The increased screen size advance was met with the tablet, but it came with an added cost of weight. Future advances can reduce the weight of the tablet and/or involve folding screens or the like. It is still unclear as to whether the handwriting recognition and/or touch screen functionality of the tablet is advanced enough to meet the desire for easier data entry. Both seem to depend heavily on how the software system is designed (or set up) to capture order entry. Future studies detailing the needs of MPOE compared with CPOE will definitely affect the success of mobile technologies in healthcare. Finally, database integration between multiple software systems in healthcare can improve, and its quality will definitely affect the mobile user's experience. The more integrated systems become and the quicker the information can be accessed will only fuel mobile technology growth. Information "on the move" is not valuable if it takes too long to access it.

Future Directions

The knowledge obtained from this study can be used as the basis for future in-depth studies on tablet computer usability between specialties, departments, and medical centers (Table 3). The broad testing method can be used as a starting point for health administrators trying to determine if the tablet computer can be a powerful tool in their particular health care settings. Tablet computers may improve productivity, assist with CPOE and the integration with the electronic medical record, and more importantly improve patient care and satisfaction by increasing time with patients at the bedside. However, integrating information from MPOE studies and adjusting networked software systems to take advantage of mobile technology assets will likely help to address many of the usability issues discovered in this study. Future usability studies can be done in different medical settings using this modified discount usability testing method to determine if the tablet computer could be helpful or not in the various jobs found in distinct settings. For example, as shown in this study, in the ED the tablet may be more useful to residents than attendings due to their need to be more mobile. Future studies can learn from this analysis to attempt to modify software user interfaces to take advantage of tablet computing features prior to usability testing. Usability analysis on mobile devices in settings which are not MPOE compatible makes study of the form factor in isolation nearly impossible. The mobile computing device is part of a larger mobile computing implementation effort, with usability issues usually not isolated to the form factor itself.

Recommendations for Improving Tablet PC Usability in Healthcare Settings
• Reduce device weight • Develop software optimized for touch screen interaction with health information software systems • Develop mobile computing plans for particular settings that incorporate workflow considerations and available electronic resources • Provide adequate technical support

Table 3. Recommendations for Improving Tablet PC Usability

Conclusion

This study showed that an economic and efficient modified discount usability method can be an effective approach to determining basic usability issues of a tool. It can also be used as a hypothesis generating method that forms the basis for future in-depth studies. This usability analysis also showed that it is still unclear whether or not current generation tablet computers can be useful in healthcare settings. However, it did uncover more defined questions and concerns with the tablet that could be addressed in the future. Of particular note is that in many cases, the form factor was of less concern to the evaluators than the limitations that feature sets in the software and/or the workplace setup imposed on them. Software optimized for this new hardware device may be necessary before the full potential of the tablet computer is realized.

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