A MOBILE TABLET APP FOR CLINICAL EVALUATION AND MEDICAL EDUCATION: DEVELOPMENT AND USABILITY EVALUATION

A MOBILE TABLET APP FOR CLINICAL EVALUATION AND MEDICAL EDUCATION: DEVELOPMENT AND USABILITY EVALUATION

by

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ABSTRACT

The rise in popularity of smartphones and tablets has sparked substantial interest among healthcare providers. Increasing number of medical schools have launched curricula targeted for mobile tablets. A mobile tablet that facilitates clinical documentation can enhance the mobility of residents and physicians by eliminating the need to be tethered to a workstation. Considering the popularity of Apple's iPad, a clinical evaluation tool for syncope was implemented on an iPad to test its usability in this environment.

The primary objective of this thesis is to develop a mobile tablet app for clinical evaluation and to assess its usability. The contents of the app are based on clinical practice guidelines. The app facilitates clinical evaluation using structured, pre-populated items and unstructured free-text narratives. The participants of this study used the app and paper in pre-determined sequences to document clinical evaluation of a given scenario. A System Usability Scale (SUS) questionnaire was used to gather feedback on usability. A comparison questionnaire gathered participant preferences between app and paper.

This study showed that evidence-based app could be developed, with an emphasis on usability during design and development. During the study, participants recorded more 'structured' than 'unstructured' free-text information on the tablet. The SUS

scores indicated an above average usability score for the app. However, participants rated paper above the app in overall comparison. Future studies are needed to determine whether the level of detail of clinical information presented in mobile tablet apps have a negative effect on participant acceptance.

This thesis is dedicated in loving memory of Isabel Mathew

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LIST OF ALL ABBREVIATIONS

AFMC - Association of Faculties of Medicine of Canada

BYOD - Bring Your Own Device

CanMEDS - Canadian Medical Education Directives for Specialists

CDSS - Clinical Decision Support System

CPOE - Computerized Physician Order Entry System

EBM – Evidence Based Medicine

EMR – Electronic Medical Record

IDE – Integrated Development Environment

OS – Operating System

PACS - Picture Archiving and Communication System

PDA – Personal Digital Assistant

PHIPA - Personal Health Information Protection Act

PPP - Preferred Practice Pattern

RCPSC - Royal College of Physicians and Surgeons of Canada

SDK - Software Development Kit

SOAP - Subjective Objective Assessment Plan

SME - Subject Matter Expert

SUS - System Usability Scale

TLOC – Transient Loss of Consciousness

WEP - Wired Equivalent Privacy

1. INTRODUCTION

The mobile technology landscape has changed drastically in the past ten years. Consumers are spending less time on traditional personal computers and are migrating towards mobile devices such as tablets and smartphones (Huberty, et al. 2011). Smartphones and tablets of varying dimensions offer added features such as built-in cameras, global positioning systems and most importantly 'apps' for users. This chapter gives an overview of the mobile industry, with a key focus on the healthcare sector. The chapter also highlights important facets of medical education. Later on in this chapter, the concept of usability is introduced and the research questions to be addressed in this thesis are presented.

1.1 Mobile Industry

The mobile industry was transformed drastically with the introduction of Simon, the first smartphone, in 1993 (Tynan 2005). This device combined features of the cellular phone, fax, E-mail, pager, paperless notepad, address book, calendar, and calculator in one hand-held unit (IBM 1994). A few years later, the mobile industry witnessed yet another transformation with the introduction of the personal digital assistant (PDA). The first PDA was introduced by Palm in 1996 and they became popular because of their relatively low price and their ability to connect to computers via serial cables (PC Magazine n.d.). Vendors continued to introduce newer models of PDAs with improved features that endeared the device to customers. By 2000, the first modern mobile operating system (OS), Symbian, was launched. Each of its releases was accompanied by a Software Development Kit (SDK), including emulators and cross compliers (Nokia 2002). The flood of mobile OS introductions continued, and by 2010 some of the most popular platforms were iOS, Android, webOS, Bada, and Windows Phone OS. By the end of 2011, the top five players in the mobile phone market were Nokia, Samsung, Apple, LG Electronics and ZTE (IDC 2012).

The landscape of the mobile industry changed in 2010 with the introduction of Apple's mobile tablet - iPad. Even though mobile tablet technology was introduced in 2000, iPad revolutionized the mobile industry with its simple design and non-PC characteristics (Gruman 2011). Since then, other manufacturers such as Samsung, Motorola, HP, and RIM have entered the market, and several have even abandoned the tablet market due to lack of sales. Apple continues to dominate the tablet market with a 62% unit share (Morgan Stanley Research 2012). The most recent estimate is that worldwide mobile tablet sales will reach 118.9 million in 2012 (Gartner 2012).

Contrary to general expectations, consumers have been using smartphones not to make telephone calls, but to consume data and media services (Chan 2011). These services can be performed with much ease on a tablet, as most tablets have larger display screens than smartphones. Tablets have gained popularity among consumers primarily due to their attractive form factors. The larger display area on tablets enables easy web surfing, browsing, video applications, and content creation. Many enterprises allow employees to "bring your own device" (BYOD) which basically permits employees to use their personal mobile tablets and smartphones at work. It is estimated that enterprise sales of tablets will account for 35% of total tablet sales by 2015 (Gartner 2012).

1.2 Mobile Technology in Healthcare

The rise in popularity of smartphones and tablets has sparked substantial interest among healthcare providers. Mobile health (m-health) applications are seen as a convenient solution for the information intensive healthcare sector. Software vendors and developers are eager to cater to the needs of healthcare providers and have launched numerous apps for various device models. For instance, over 5200 apps are available at the time of writing this thesis under the medical category from Apple's app store. For the Android market, nearly 600 apps are available under the medical category from Google Play.

Clinicians use smartphones for patient care and for updating their own medical knowledge (Boulos, et al. 2011). Hospitals and clinics have supported the use of mobile technology for communication. Recent advancements in mobile technology and reliability of wireless connections have prompted physicians to adopt this technology. Furthermore, information systems such as electronic medical record systems (EMRs) and picture archiving and communication systems (PACS) can be accessed using smartphones (Baumgart 2011). Smartphones can also facilitate peer-to-peer interaction among healthcare providers. However, the medical community has serious concerns in about managing security and privacy of patient data when clinicians use mobile applications that are not under central control.

Physicians have adopted mobile technology at a very high rate - about 62% of physicians use mobile tablets (Terry 2012). Tablets offer a simple, yet appealing touch screen interface for the user. The large screens on tablets makes the devices ideal for displaying patient clinical information, a task that is challenging with smartphones. For physicians, carrying a tablet would be similar to carrying a paper chart. Medical applications such as computerized physician order entry systems (CPOE), electronic prescribing, EMR systems, alerts, and communication systems, can be accessed through tablets. The touch screen capability available on tablets can eliminate the need for keyboards. Using mobile apps that are customized for each medical specialty on tablets can further enhance user experience during patient encounters.

1.3 Undergraduate and Post-graduate Medical Education

Medical education encompasses both the theoretical and practical aspects of medicine. In North America medical students normally enroll in three or four year programs after undergraduate training before moving onto residency programs. In Canada, 17 faculties of medicine offer undergraduate education in medicine (AFMC 2007). These university-affiliated faculties provide unparalleled learning environments to medical students, equipping them with problem solving, critical thinking and teamwork skills in addition to imparting scientific knowledge. During the undergraduate medical education program, students gather clinical experience working alongside residents and experienced clinical faculty.

Canadian medical education has won international acceptance since the 1950s. Canadian medical educators have introduced innovative teaching methods that have advanced the curriculum to the forefront in medical education. In the late 1960s and early 1970s Canadian medical schools introduced radical methods including courses that introduced medical students to patient care with the support of computer-assisted teaching (Dauphinee 1993). The 1960s also witnessed important developments in the regulation of medical education when the Royal College of Physicians and Surgeons of Canada (RCPSC) moved post-graduate medical education from teaching hospitals to universities (Naimark 1993). In 1996, the RCPSC created the Canadian Medical Education Directives for Specialists (CanMEDS) program that outlined seven core competencies (Mickelson and MacNeily 2008). These core competencies have shaped the curriculum for post-graduate medical education in Canada to a certain degree. Effective use of information technology for patient care and self-education is recognized as a sub-competency of one of the core competencies (Baerlocher and Asch 2006).

In their final year, medical students apply to the Canadian Resident Matching Service and are then matched for entry into post-graduate medical training. The matching process includes positions for entry residency (year 1) into family medicine, medicine subspecialties, and pediatric subspecialties (CaRMS 2011). Instructional methods for residents range from academic half days, rounds, case presentations, seminars and faculty mentorship of small-group role-playing activities (Mickelson and MacNeily 2008). Upon commencement of residency, residents continue with their role as scholars and guide medical students in clinical settings. Residents provide direct patient care under the supervision of experienced physicians (AFMC 2012). Residents who have completed their training will have to pass certification examinations before they can become independent clinicians and be paid for their services. In addition, these graduates must pass licensing examinations to practice medicine in Canada.

1.3.1 Modes of Computer-based Learning in Medicine

Medical education has been transformed by information technology solutions. Computer-assisted learning has facilitated teaching of a wide range of topics, including basic science and advanced surgical procedures. While developing information technology based teaching solutions for medicine, it is necessary to consider teaching strategies. The modes of computer-based learning in medical education are explained below (Dev, Hoffer and Barnett 2006):

a) Drill and practice – In this method, teaching material is presented to the student and the student is evaluated immediately using multiple-choice questions. This method can be helpful to students with varying skills and helps the instructors to focus on more challenging areas of the subject.
b) Didactic – Computers can be used to deliver instructional materials such as lectures and reference material. Students can consume these materials at their own pace and timing. The only caveat is that learning occurs asynchronously and therefore instructors may not be available round-the clock to answer student questions.
c) Discrimination learning – This method teaches students to distinguish among clinical presentations. The learning module usually introduces important differences between the standard clinical presentations of a disease or disorder and then explains additional or rare presentations of the condition.
d) Exploration and structured learning – In exploration learning, students have the freedom to choose their course of interaction with the learning module, while in structured learning, the system choices are determined a priori.

e) Constrained and unconstrained response – Computer systems can offer constrained lists of responses for a particular scenario or allow students to specify actions using natural language.

f) Construction – In this method, students learn by putting together various pieces of a large problem or object.

g) Simulation – In this method, computer simulation of a patient or situation is used to teach medical students. The student usually observes and queries the system to find out more about history, physical exam findings, and lab results to reach a diagnosis. In some simulations, students are required to guide or direct the progression of a simulation. Simulations can be done by individuals or in groups of similar students or with students from other disciplines.

h) Feedback and guidance – While learning with the assistance of computer systems, students are provided feedback, including verification of student responses, reference material, and hints.

i) Intelligent tutoring systems – Students interact with computer systems that monitor and intervene, providing an efficient learning framework for students. The computer system will assess the student's knowledge and move on to other topics or issues or continue to direct the student until certain learning goals are reached.

1.4 Information Technology in Clinical Practice

The primary focus of physicians during a clinical visit or encounter is to provide quality patient care. Increasingly the shift towards team-based patient care has necessitated the need for systematic documentation of clinical encounters. It is essential that information regarding a patient encounter such as chief complaint, history of presenting illness, past history, family and social history, physical examination, important test results, current medications, impressions and recommendations to the patient be recorded accurately for future reference. There has been an increasing drive towards EMR adoption in North America. An EMR system facilitates comprehensive views of patient information during clinical encounters. The information that can be stored in an EMR includes patient demographics and history, allergy, medications, diagnosis and treatment plans. However, entering patient information into an EMR system during a clinical encounter can be challenging for less experienced physicians. A study conducted at US Veterans Affairs primary care clinic reported that use of computers adversely affected resident's time for patient interaction during the encounter (Rouf, et al. 2007). Another challenge of using EMR systems is in the varying preference of physicians for how to record patient data in the information system. For example, younger physicians prefer typing (often during the encounter) whereas experienced older physicians prefer dictation (Smelcer 2009). A mobile app that exploits the touch screen capability of tablets can appeal to physicians of all ages (Katz 2012).

Development of effective electronic patient records is constrained by four factors: a) standardized clinical terminology; b) privacy, confidentiality and security concerns; c) data entry challenges for physicians and d) integration with other information systems (Shortliffe and Blois 2006). Patients and providers will not trust a system that does not address privacy and security concerns. In fact, physicians perceive patient privacy as one of the factors hindering the use of mobile technology in healthcare (Modahl 2011). Government regulation such as the Ontario Personal Health Information Protection Act (PHIPA) mandates that access to patient information be restricted to providers involved in the patient's circle of care (Service Ontario 2010).

The use of wireless technology creates additional privacy challenges. Most intranets use the IEEE 802.11 wireless LAN standard, which has major vulnerabilities in its underlying wired equivalent privacy (WEP) protocol (Boland and Mousavi 2004). In the healthcare environment, when mobile devices are used to transfer data wirelessly, adequate measures must be taken to enhance security and restrict access.

A mobile tablet that facilitates clinical documentation can enhance the mobility of physicians by eliminating the need to be tethered to a workstation. Integrating 'option selection' with the touch-screen capability of tablets can further enhance the user experience. Apps can be developed with clinically relevant content that can be accessed and used during patient encounters. In an academic learning environment, such apps can also function as a learning tool for residents (Coovert, et al. 2012) and students who are taking part in patient care. A mobile app can be a powerful tool in medical education if multiple modes of computer based learning are incorporated.

1.5 Significance of Usability

Usability of a product is associated with its context of use. The five usability attributes are learnability, efficiency, memorability, errors and satisfaction (Nielsen 2009). Usability is therefore not a one-dimensional property of a product. Factors such as how well a user learns and uses a system, how often a user makes an error, how well a user recalls features based on previous experience with the system, and overall user satisfaction are all associated with usability. These factors are usually measured during usability testing. The usability of a product can be assessed using usability evaluation or usability testing or a combination of these two methods (Usability.gov 2012).

Usability in healthcare has particular importance; even the slightest usability issue can have a negative impact on patient care (HIMSS 2009). Usability issues with medical devices have even led to fatal accidents (Sawyer 1996). Usability testing early in the development process can identify potential problems with a product. Furthermore, usability and cognitive evaluation are accepted methods in evaluating new training methods for medical curricula (Dev, Hoffer and Barnett 2006).

Mobile tablets, particularly iPads, promote efficiency in learning and collaboration among students (ACU 2011). Textbooks can be made available to students as e-books, thereby eliminating the need to acquire and use printed versions. Some medical schools have started to supply iPads to their students (Paddock 2012). Institutions have started encouraging students to bring their own tablets to access learning materials electronically. As usability plays a critical role in healthcare, a usability study of an app developed as a teaching tool for medical students and residents is proposed in this research. This study addresses the following research questions:

1. Can a mobile clinical education app for syncope be made for medical students and residents with its core content based on existing clinical practice guidelines?
2. Does the usability of the app influence the quality of the patient history recorded by medical students and residents?

The next chapter summarizes the literature survey related to this research. The third chapter discusses app development and usability testing. The results are presented in the fourth chapter. The final chapter covers discussion of results, scope for future research, and conclusions.

2. LITERATURE REVIEW

The literature review in this chapter is divided into two sections. The first section includes published literature on clinical aspects of the research - medical education, evidence based medicine (EBM) and clinical practice guidelines. Syncope is also discussed in the first section as it is being used as an exemplar for developing the tool used in this study. The second section of this chapter covers literature on technical aspects - use of technology in medical education, and usability in medical applications.

2.1 Medical Education in Canada

Medical education is offered as a three or four-year program in Canada (AFMC 2007). The curriculum encompasses both the theoretical aspects of medicine and practical skills. Usually, by the end of the penultimate year, students enter clinical clerkship during which time they are guided by residents and experienced physicians while interacting with patients. Choices of clinical clerkship rotations are strongly influenced by the student's preferred residency program (Gray and Ruedy 1998). Once matched for a residency program, residents begin their training, in an environment that involves multiple roles. Residents learn in clinical settings by means of grand rounds, case presentations, lectures, simulations and seminars (Mickelson and MacNeily 2008). Aside from continuing with the learning process, residents teach medical students and provide direct patient care under the supervision of staff physicians (AFMC 2012).

Patient care can be improved by teaching medical students and residents knowledge and skills of practice-based learning and improvement (Ogrinc, et al. 2003). The basics of practice-based learning are introduced in medical schools. One method used to evaluate resident competency in practice-based learning is to review patient records against accepted patient care standards (Hayden, Dufel and Shih 2002). Traditional paper charts allow free text, providing the flexibility to document patient information and annotate critical information. These charts are usually completed after a patient encounter or at the end of a shift. Reviewing such charts can be laborious and may lead to error due to misinterpretation of handwriting. Information technology solutions can facilitate data entry, storage and retrieval of patient information. The electronic patient records can then be evaluated with considerable ease for quality against accepted patient care standards. Implementing electronic patient records on a mobile platform can provide access to information at the patient's bedside. A medical student can use a mobile solution for both patient care and academic work. One study reported that medical students had more complete documentation of patient information with PDAs than with paper (Kurth, Silenzio and Irigoyen 2002).

Medical informatics is the application of information technology tools to help clinicians diagnose and treat patients. Behrends, et al. (2011) examined perspectives of medical students towards medical informatics and found that most students realized its importance but at the same time failed to welcome the integration of medical informatics into their curriculum. A suggested alternative to a standalone medical informatics course is to integrate the required information and training with clinical subjects, thereby using appropriate information technology solutions as part of the medical curriculum. In medical practice, computers should be used in a manner that complements personal knowledge and clinical skills (Friedman 1997).

Based on the available published evidence, a decision was made for the current research to develop a mobile tablet app, intended for use in a specific teaching support role in the Canadian medical curriculum.

2.2 Evidence-Based Medicine

EBM is defined as "the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett, et al. 1996). In this approach, healthcare providers use the best evidence available, along with patient characteristics, to make clinical decisions for patients (McKibbon 1998). The strongest evidence can come from randomized clinical trials, meta-analysis and other clinically relevant research. Educating clinicians about the strength of published evidence can reduce ineffective, expensive or potentially harmful interventions (Belsey 2009) while at the same time maximizing appropriate care. Medical students can be trained to use published evidence as part of their curriculum. Curricula based on EBM are popular in residency programs in internal medicine, family medicine, paediatrics, obstetrics and surgery (Hatala and Guyatt 2002).

Studies have been conducted on the application of published evidence by medical students. Schwartz and Hupert conducted a study with 164 graduating medical students. The students examined a standardized patient with whiplash injury and performed focused physical examination and history taking (Schwartz and Hupert 2003). Afterwards, students were asked to decide about ordering radiographs, and their clinical decisions were rated before and after reading a decision rule that argued against the test. The study concluded that the students had learned the concept of appropriate diagnostic testing, but lagged in applying evidence to a particular patient.

2.2.1 Clinical Practice Guidelines

A common implementation of EBM is to use clinical practice guidelines during medical decision-making (Timmermans and Mauck 2005). Clinical practice guidelines are developed for specific clinical situations and are ideally evidence-based. Vast numbers of guidelines are available to clinicians; some derived from meta-reviews of multiple large randomized clinical trials while others were developed with the aid of small clinical trials, other research, opinions of experts and focus groups. A search from the US National Guideline Clearinghouse listed over

2500 total guidelines (AHRQ 2012). The availability of large numbers of guidelines makes it difficult for practitioners to ascertain high quality and reliable clinical practice guidelines that are appropriate to their clinical situation (Institute of Medicine 2011). Furthermore such large numbers of guidelines can be overwhelming for practitioners and may lead to poor adoption of guidelines in clinical practice. Adherence to recommended guidelines is relatively low at all levels of clinical training (Kogan, Reynolds and Shea 2001) and practice.

Few studies have evaluated residents' adherence to guidelines. For example, resident compliance to ophthalmology guidelines, particularly the Preferred Practice Pattern (PPP) guidelines regarding cataracts in adult eyes was studied at a US Veterans Affairs Medical Center (Niemiec, et al. 2009). EMR records of 129 patients were reviewed retrospectively and compliance with all 39 elements of the PPP guidelines were analyzed. The study found that mean compliance with the PPP was 81%. However, the study also discovered that compliance was below the mean for PPP elements requiring patient input or assessment. Another study conducted at a US university-based internal medicine training program compared the performance of interns, residents and faculty members on measures of quality care in prevention and disease management (Kogan, Reynolds and Shea 2001). The study used abstracted patient charts based on a tool that included the recommended guideline for general health prevention and management, in addition to relevant patient and provider information. This study found no significant differences among the performance of interns, residents and faculty members.

Evaluation and management guidelines are often published by accredited organizations that help physicians to make decisions regarding patient care. These guidelines specify “gold standards”, including the best available diagnostic test for a given disease, condition or situation. Many treatment guidelines also exit. Absence of gold standards can lead to unnecessary tests, thereby increasing healthcare expenditures (Moya, et al. 2009).

2.3 Syncope Evaluation

Syncope or fainting is defined by transient loss of consciousness (TLOC), which can affect children and adults. Syncope is a common condition in general clinical practice. In the majority of cases, it is caused by a benign condition. However, in a small number of cases, syncope represents a warning sign for a more severe underlying cardiac or neurologic condition, which could be fatal if not properly evaluated with a thorough history and physical examination as an initial assessment. The defining characteristics of syncope include TLOC with rapid onset, resulting in loss of postural tone and falling, followed by spontaneous and complete recovery (Miller and Kruse 2005) with or without intervention.

Traditionally, syncope is classified into three groups, based on the cause– neurally mediated, cardiovascular and non-cardiovascular syncope (McLeod 2001). Neurally mediated syncope is generally benign. Cardiac causes of syncope can include arrhythmias and structural abnormalities and can be fatal if not diagnosed and treated properly and timely. Non-cardiovascular causes generally include epileptic seizures and psychogenic causes. However, as the efficacy of therapy is mostly dependent on the mechanism of syncope, and the same mechanism of syncope may be present with different etiologies, the more recent approach has been to classify syncope based on mechanism (Brignole and Hamdan 2012). The varied presentations of syncope combined with disorders that have syncope-like presentation add to the complexity in evaluation of syncope.

The primary goal in evaluating patients with syncope is to differentiate a patient with syncope due to a benign condition such as vasovagal syncope (the common faint) from the patient with syncope due to a more severe cardiac, neurologic or metabolic condition. Patients with an underlying cardiac condition such as myocardial ischemia, life-threatening cardio-genetic diseases and Wolff-Parkinson-White syndrome (Strickberger, et al. 2006) may be at increased risk of death. In the evaluation of patients with syncopal episodes, a detailed history and physical examination can lead to clinical diagnosis of vasovagal versus non-vasovagal syncope (Brignole and Hamdan 2012). Usual care is based on the patient's "chief complaint" or presenting symptoms, and patients are asked a set of evaluation questions by their attending physician. While examining patients, the doctor must carefully summarize the relevant clinical history followed by thorough physical examination. These questions and physical examination findings can be standardized, based on clinical practice guidelines for syncope.

A recent study has shown that using standardized syncope assessment along with decision support software based on guidelines decreases the cost per diagnosis (Brignole and Hamdan 2012). Studies have indicated that carefully obtained history is crucial for the diagnosis of syncope (McLeod 2001). Considering the complexity in syncope evaluation, an iPad app was developed in this research project for the evaluation of syncope, with a focus on capturing comprehensive patient history and physical examination. Medical students and residents tested the usability of the app by using it for clinical evaluation of a given scenario of syncope. Details of the experimental design are covered in section 3.4.

2.4 Information Technology in Medical Education

Introducing medical students and residents to information technology solutions can familiarize them with systems that are likely to be present in clinical environments. These technology solutions can range from reference tools and medical calculators to clinical decision support systems and EMRs. A study on the outcome of technology in medical education reported that medical residents who completed web-based instruction showed significant improvement on knowledge tests over residents who received paper-based instruction (Westmoreland, et al. 2010). The study used a randomized controlled trial to compare postgraduate year 1 resident knowledge and clinical performance after web-based and paper-based instruction. The web-based instruction included four modules, one each for dementia, depression, falls and urinary incontinence. These modules were based on evidence-based best practice content reviewed by academic geriatricians. The residents were randomized to receive web-based or paper-based instruction during their month long ambulatory rotation. The educational intervention effect in this study was evaluated by comparing the scores of pre- and posttest questions given during web-based or paper-based instructional methods.

Portable technology for medical education has been evaluated from several perspectives and several are elaborated here. PDAs became popular, predominantly due to their small size and ease of use for the mobile user. The studies involving PDAs in medical education showed varied results. In a Norwegian study, medical students who were provided with PDAs failed to use the device for information gathering and learning (Smørdal and Gregory 2003). However, a systematic review of the medical literature found that 60% to 70% of medical trainees used handheld computers, with reference tools and clinical computational programs being the most widely used applications (Kho, et al. 2006). The solution to adoption of devices such as PDAs for reference and patient care might be related to resident exposure to such devices during their training. In fact, Mattana et al. speculated that making PDA use a required criterion early in medical training could lead to continued use of the technology for clinical purposes (Mattana, et al. 2005).

Smartphone technology is increasing in popularity among clinicians (Goedert 2012). Physicians use various types of mobile apps for clinical decision-making. Clinicians are using apps that provide reference material, treatment algorithms, and general medical knowledge (Franko and Tirrell 2011). An iPhone app implemented for anesthesiologists at a US academic medical center facilitated visual observation of the patient through access to real time operating room videos, patient vital signs, integrated EMRs and voice and text communication. The study did not focus on improving efficiency, but evaluated user acceptance for 40 anesthesiologists who consistently used the application as a situational awareness and supervisory tool for perioperative environment (Lane, Sandberg and Rothman 2012).

Recent studies have further explored the use of mobile tablets in medical education. A survey among radiology residents found that 81% of the residents believed that they would spend more time learning if they were provided with mobile tablets (Korbage and Bedi 2012). Some of the studies were specific to Apple's mobile tablet, iPad. In fact, an ongoing multi-year study at a US medical school found three principal areas of iPad use among residents: education, professional and administrative tasks, and patient education and communication (Coovert, et al. 2012). In this study, the entire incoming class of pediatric residents received iPads.

These residents were shadowed and interviewed over the course of their first year of training. The study plans to use the feedback from residents to retain apps that received positive feedback and eliminate apps that received negative feedback.

A recent case report from United Kingdom indicates that iPads have been used as a training tool for junior surgeons (Sadri, Murphy and Odili 2012). Peri-operative medical photography images were uploaded to iPads and a common photo-editing app was used to plan local flaps. These base images provided a realistic format for trainees to plan excision of skin tumors and discuss potential reconstructions with experienced surgeons. Fontelo et al. reported that 3rd and 4th year medical students used iPads for medical education in pathology and histology (2012). The study focused only on student experience while viewing virtual slides on a local network and a remote image server.

In a study at a US medical institution, 115 internal medicine residents were given iPads with shortcuts to EMRs, publications and paging systems on each tablet's home screen (Patel, et al. 2012). The residents were surveyed a month before and 4 months after deployment. Additionally, time frames of all patient care orders in the first 24 hours for new patient admission were extracted from EMRs for the same 3-month period before and after iPad deployment. Residents reported timesavings of approximately one hour a day with iPad use. The study also found that more orders were placed during the first 2 hours of new patient admission in the postdeployment period than in the pre-deployment period.

The studies discussed in this section indicate that implementation of iPads among residents has been associated with improvements in both perceived and actual resident efficiency. Considering the popularity and the educational potential of iPads, it was chosen for the current research as the platform for app development. Details of the app development process are covered in section 3.3.

2.5 Usability in Medical Applications

Usability is defined in terms of five attributes: learnability, efficiency, memorability, errors, and satisfaction (Nielsen 2009). It is difficult to measure usability well as it is tied to the context of user tasks, the product, and the environment in which it is used (Lewis 1993). However, early detection of usability issues is critical in medical applications because usability issues can induce inefficiency and lead to errors. Information technology systems used in healthcare can be complex due to the intricacy in workflow within clinics and hospitals and the sophistication of the users. The challenge for developers is to make these complex systems usable.

Various methods of usability assessment exist, each providing diverse insight into usability issues. Usability evaluation and usability testing are two ways of assessing usability (Usability.gov 2012). Typically usability specialists perform usability evaluations and conduct usability tests with representative users of a product. Usability evaluations and usability tests can be used to identify potential usability issues with a product. Most often usability evaluation reveals issues that can be quantified with a follow-up testing session. In some scenarios, usability experts may not be qualified to judge if required information is present in the product. In such cases, usability experts and subject matter experts collaborate to conduct usability evaluations. Usability tests during the development process are important to reduce errors in information systems and CDSSs intended for use in clinical practice (Kastner, et al. 2010). Healthcare organizations are encouraged to conduct internal usability assessments with clinical staff prior to purchasing a new medical device or a new model of an existing device (Sawyer 1996). Such assessments help organizations determine usability issues in the actual working environment of the device.

Heuristic evaluations are usually conducted by one to three evaluators who examine the interface and check for compliance with usability heuristics (Usability.gov 2012). This technique provides fast and cost effective feedback to designers. However, this method fails to identify areas of the interface that are compliant with the heuristics. Heuristic evaluations can reveal more minor problems and overlook major missing functionalities of the interface. Heuristic evaluation can be an efficient and low-cost method in evaluating patient safety features of medical devices (Zhang, et al. 2003).

Tools such as surveys and questionnaires, focus groups, interviews and user observations can provide valuable information on usability (Rosenbaum 1989). In a study conducted at a US medical school's emergency department, attending and resident physicians evaluated a mobile tablet and rated the severity of the identified issues using a survey (Andon 2004). The study indicated that both attending and resident physicians were not certain about the benefits of the tool. However, the study indicated that medical residents may benefit more from the mobility offered by tablets than would the attending physicians. It was decided that usability evaluation of the app with medical students and residents was necessary to uncover critical usability issues during the research involved in this thesis. Details of participant selection and usability assessment are covered in chapter 3.

This chapter highlighted clinical and technical topics related to this thesis. The first section explored learning in the Canadian medical education system. Published literature on application of EBM by medical students and residents were then reviewed. Studies pertaining to adherence to clinical practice guidelines across all levels of training were reviewed next. As syncope is the focus of this thesis, an overview of this condition and challenges in evaluating patients with syncope were elaborated. Technical topics began with a review of the literature on a wide range of information technology solutions in medical education. The final section covered usability in medical applications. This thesis project aims at developing a syncope evaluation app for medical students and residents and to assess the usability of the app. The goal of the mobile tablet app developed in this research is to use the syncope evaluation guidelines to encourage medical students and residents to conduct patient evaluations consistent with these guidelines. Further, the usability evaluation of the app is oriented towards uncovering potential usability issues and to reveal the perceptions of the users participating in the trial of the app.

3. METHODS

This chapter outlines the planning, design and development of the mobile education app. The experimental design is discussed towards the latter part of this chapter. This chapter also includes a discussion of why syncope was chosen for the topic, the choice of participants, and the evaluation methods.

3.1 Planning

One of the first decisions to be made in the planning phase was to decide on the app development approach. In the highly fragmented mobile market, development and maintenance for multiple platforms can be expensive. Mobile app development approaches can be either native, web based or hybrid (IBM 2012). In the native approach, an application is developed for a particular platform with the intention of exploiting device level features. Native apps offer the convenience of native look and feel coupled with fast performance. The web-based approach relies on reliable online connectivity as these apps are accessed via a browser. Hybrid apps are essentially web apps wrapped in a thin native container to emulate the native look and feel. The hybrid approach combines the best of native and web apps. This approach allows developers to develop only once and to deploy on multiple platforms. However, the app developed must be tested using customized tools for cross-platform testing.

The aim of the thesis project is to develop a mobile tablet app based on clinical practice guidelines and assess its usability. Deployment on multiple platforms was considered out of scope for this research. Additionally, only the author was involved in the development process. Considering the projects goals and availability of resources, web and native development approaches were considered as possible development options. However, web development lacked the rich user experience that the native method would offer. Therefore, it was decided to develop a native app.

The next step was to select a suitable platform for development and implementation. One tablet stood out in terms of popularity and proven use in medical education. Studies showed that Apple's iPad is increasingly used to train medical students and residents (Coovert, et al. 2012; Fontelo, et al. 2012). Furthermore, iPad was the most popular tablet in 2011 and is expected to continue as the market leader in 2012 (Gartner 2012). The iPad was therefore selected as the target tablet for app development. An additional issue in favor of the iPad is that regulations mandate strong encryption of devices and recommend not storing patient information within the device (Service Ontario 2010). These issues need to be addressed during the enterprise deployment of the app (out of scope for this thesis research).

3.2 Design

The app was designed to function as a training tool for evaluating patients with syncope. Additionally, medical students and residents were selected as target users as this group was expected to gain knowledge in syncope evaluation by using the app. This section highlights the design principles involved in the app design.

Information systems used in hospitals and clinics store patient demographic information along with medical records. The demographic information is usually used for patient identification, scheduling and billing. Information regarding height and weight can be helpful for physicians in making treatment decisions and for prescribing medications. The app design included a module for patient demographic information.

3.2.1 Clinical Content

Subjective Objective Assessment Plan (SOAP) is a knowledge exchange protocol that is used for structuring the clinician-patient encounter as well as the documented patient's medical record (Herschel, Nemati and Steiger 2001). Clinicians rely on this protocol for documenting the patient's history, physical examination, diagnosis and treatment plan. Learning the SOAP protocol is essential for medical students and residents who are increasingly involved in patient care. The design of the main hierarchy for clinical documentation in the app was based on the SOAP protocol. Contents within a SOAP branch were stored as structured data. In order to facilitate multiple modes of data entry in clinical evaluation, a 'Notes' section was included for entering free text narratives. The free-text section supported unstructured data. Fig. 1 shows a high-level flowchart of the app.

Syncope is a common condition that can affect children and adults. The challenge for physicians is to differentiate patient with syncope due to severe cardiac, neurologic or metabolic condition from patient with benign condition such as vasovagal syncope. The mobile tablet app is designed for syncope evaluation. The clinical content for the app was determined in two stages. In the first stage, a syncope guideline search was conducted on the U.S. National Guideline Clearinghouse website. Three results pertaining to evaluation or diagnosis of syncope (Moya, et al. 2009; Cincinnati Children's Hospital Medical Center 2010; Huff, et al. 2007) were selected for review. Position papers and scientific papers (Brignole and Hamdan 2012; Sheldon, et al. 2011; Strickberger, et al. 2006) were also reviewed by the author.

From the above guidelines the author extracted items for history of present illness, past medical history, family history and physical examination. A spreadsheet was then populated with these items. In the second stage, an experienced cardiologist with expertise in syncope evaluation (who supported this research as a clinical subject matter expert or SME) was consulted. The items identified in the first stage were reviewed by the SME and grouped into SOAP categories. The section on

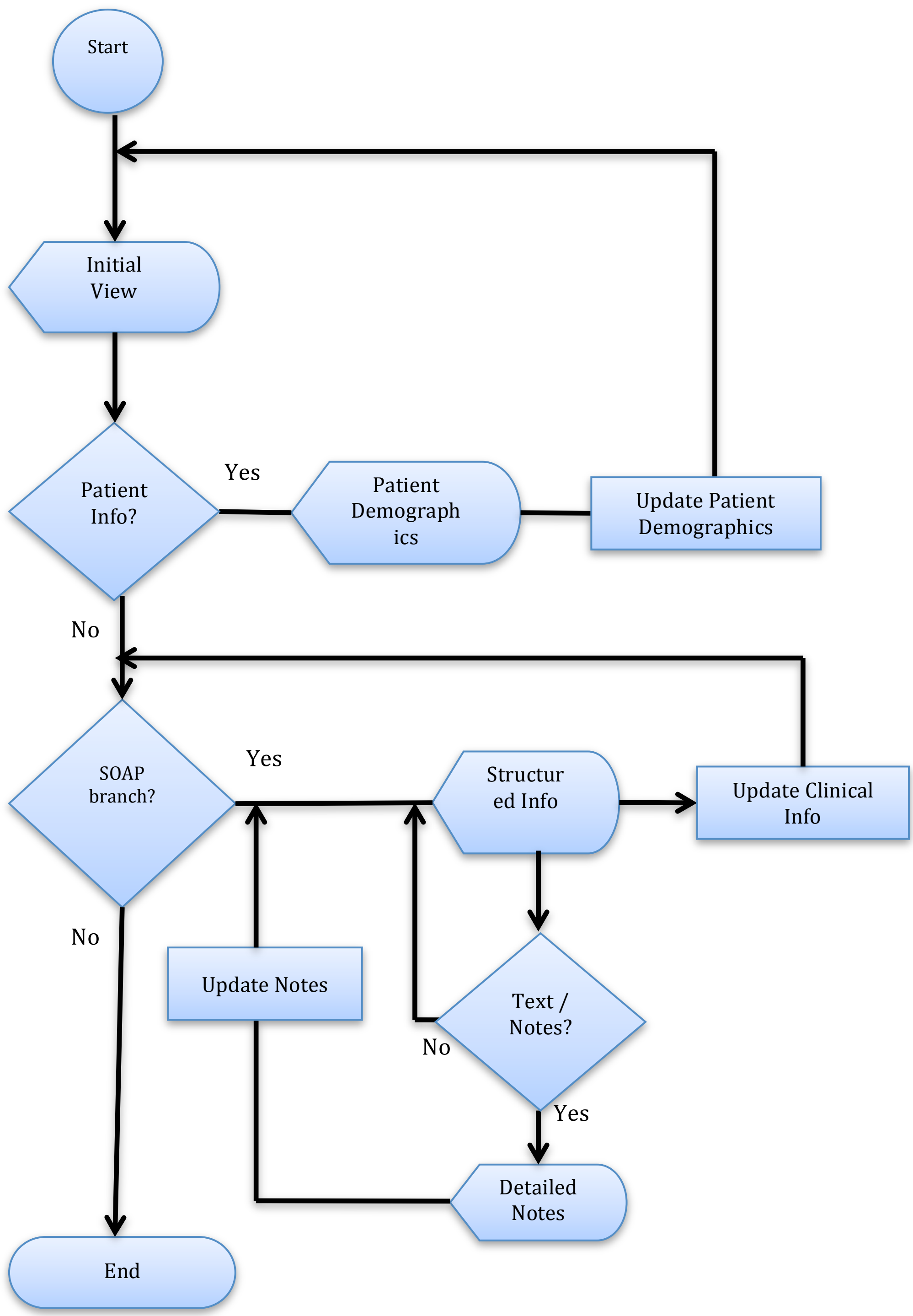

Figure 1. High-level Flowchart of App

past medical history was divided into adult and pediatric history. Items for general physical examination, cardiovascular system and neurologic system were added to the list after consultation with the SME. In addition to standard vital signs, postural systolic and diastolic blood pressure readings were added to the list. The SME also provided experience-based suggestions regarding the content of the app. Medications and allergies were added to the app content in order to give medical students and residents a realistic experience for patient evaluation.

3.2.2 Interface Design Guidelines

General interface design guidelines intended for personal computers do not necessarily apply to mobile interface design. The smaller screen size and memory of the mobile device presents significant challenges to the developer. Designers must display important content in a strategic layout without cluttering the interface. Additionally, absence of input devices such as mouse and keyboard must be compensated for by the use of gestures. The human interface guideline available for each device specifies the standards gestures supported by the device. Designers usually provide standard gestures for apps designed for particular tasks.

During the design of the app, the human interface guideline for iOS devices was consulted and applicable design guidelines and principle were adhered to. A few of the more relevant guidelines followed during the app design are as follows (Apple Inc. 2012):

- standard tap or touch gestures were used to allow user selection
- standard buttons provided by iOS were used to save the state of the app
- portrait and landscape orientations were supported
- standard text functions such as select, copy and paste were used

While designing interfaces for mobile devices, a “top-down” approach is recommended, where high-level information is presented to the user allowing the user to choose to retrieve more detailed-level information (Gong and Tarasewich 2004). This design principle was used in the interface design of the app. The initial view of the app was designed with high-level SOAP categories as separate rows. Simple gestures were used in the design of the app. A touch or tap gesture on a SOAP branch triggered the transition to a detailed view pertaining to the branch. A paper mock-up of the interface was designed by the author and approved by the SME before proceeding to the development phase.

3.3 Development

The development phase included app development and internal testing by the author. The app development process involved small increments and iterations that were time-bound and lasted up to three weeks. The app at the end of the first iteration reflected the interface designed using the paper mock-up. During subsequent iterations, advanced features were added or refined. Clinical content was also populated in the SOAP branches. A working copy of the software was demonstrated to the clinical SME at the end of each iteration. Modifications suggested by the SME were taken care of in a subsequent iteration.

3.3.1 Development Environment

The app development was done using Apple's software development kit (SDK). The SDK includes Xcode IDE, iOS Simulator and the Instruments analysis tool. The integrated development environment (IDE) facilitated user interface design, code editing, testing and debugging in a consolidated window. The IDE was installed on a laptop (Table 1). Memory and CPU usage were analyzed using the Instruments tool.

Table 1. Development and Testing Environment

	Laptop	Tablet
Model	MacBook Pro	iPad
CPU	Intel Core i7	Apple A5X
OS	Mac OS X Lion	iOS 5
Hard Disk	750 GB	64 GB

3.3.2 Usability Heuristics

Usability heuristics are platform agnostic design principles for user interface design. During development of the app, usability was considered to be paramount. Every effort was taken by the developer to ensure that usability heuristics were followed in the user interface design. The usability heuristics (Nielsen, 2005) taken into consideration during development are itemized below and a discussion of compliance with heuristics is discussed in the subsequent paragraphs:

- Visibility of system status
- Match between system and the real world
- User control and freedom
- Consistency and standards
- Error prevention
- Recognition rather than recall
- Flexibility and efficiency of use
- Aesthetic and minimalist design
- Help users recognize, diagnose, and recover from errors
- Help and documentation

In each view of the app, users were made aware of the system status by immediate feedback. When users make a selection, checkmarks appear next to the selected item. The top-level view of the app corresponds to the standard SOAP format used in clinical documentation (Fig. 2). This provides a logical documentation method for patient information. The author used standard clinical terminologies obtained from published literature to categorize SOAP branches. The SME verified the terminologies during demonstration of working copy of the app.

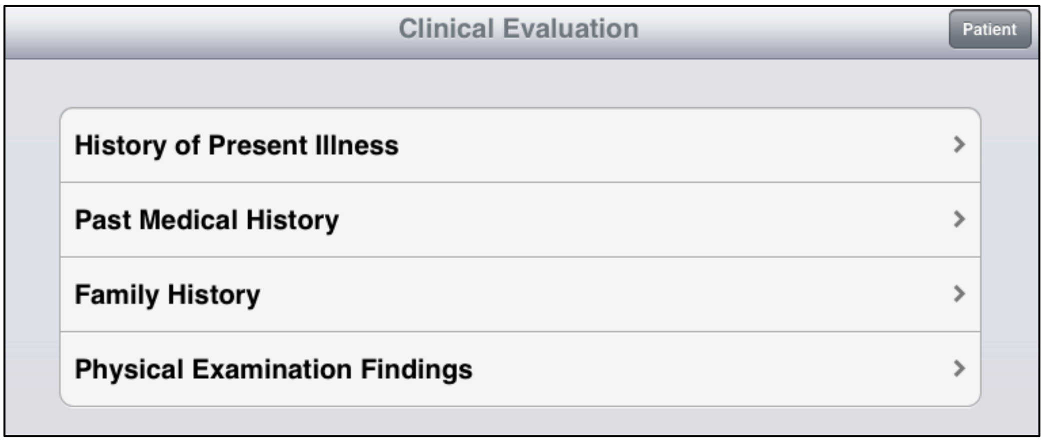

Figure 2. Top-level Hierarchy of the App

When a SOAP branch is selected, the new view shows the selected SOAP branch prominently along with an option to navigate to the previous view. Users have the option of returning to their previous state by tapping a button. This minimizes memory load on the user. Users can undo a particular selection by touching the selected row. In a similar fashion, they can 'redo' their action by touching the same row. Users have the option to cancel newly recorded free-text clinical notes by tapping the 'cancel' button in the Notes section (Fig. 3) of the app. The app uses clinical terminology to describe symptoms and diseases. Standard system-provided buttons were used to represent actions outlined by iOS Human Interface Guidelines (Apple Inc. 2012).

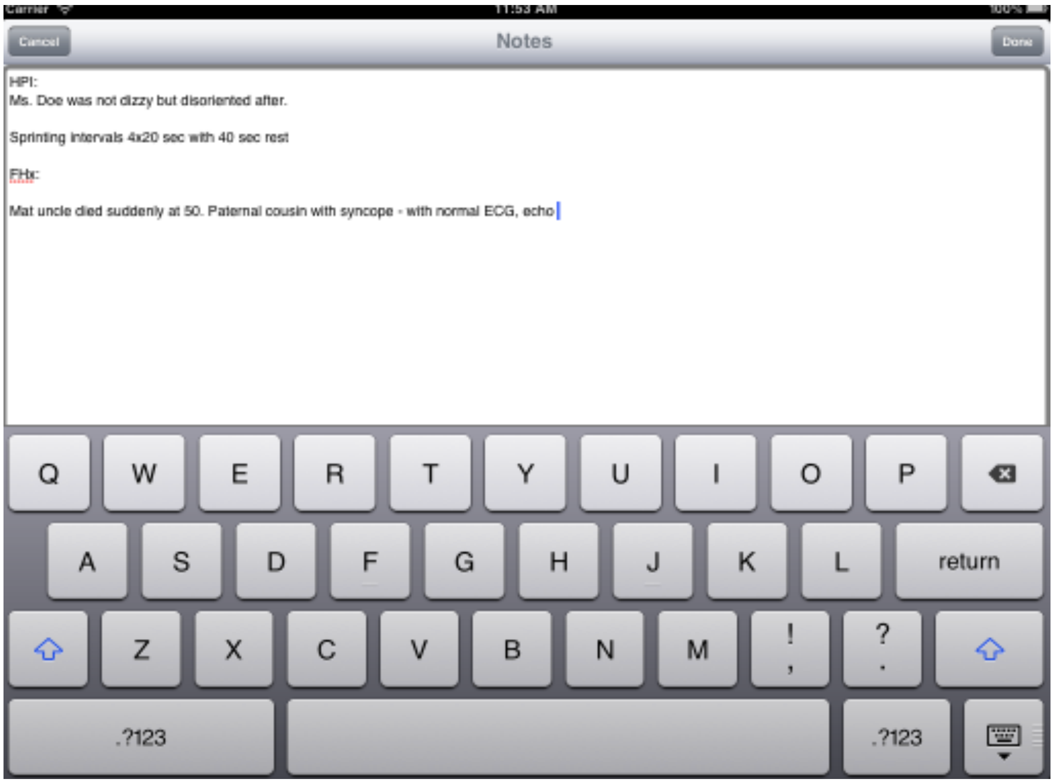

Figure 3. Notes View with Narratives

3.4 Experimental Design

The study objective was to evaluate usability of the syncope evaluation app. Ethics clearance was obtained from the McMaster Research Ethics Board before contacting participants. Participants were recruited through word of mouth. The target was to recruit 5 to 10 participants for the study. Participants were entered in a random draw to win $100. To carry out the usability evaluation, participants needed sufficient clinical knowledge to understand clinical scenarios. Medical students and residents were selected as research participants because of the educational potential of the app.

3.4.1 Objective 1

The first objective of this study was to measure the usability of the mobile tablet app. Usability is defined as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" in ISO 9241, the international standard for ergonomic requirements for office work with visual display terminals (International Organization for Standardization 1998). Usability assessment can be broadly classified into usability evaluations and usability tests (Usability.gov 2012). Most usability evaluations gather subjective data such as participant opinions and perceptions of usability along with objective data such as scenario completion time and scenario completion rate (Lewis, 1993). Subjective data are associated with user-satisfaction of the product whereas objective data are used to suggest how to improve efficiency.

A widely used usability evaluation technique is heuristic evaluation. In this method, a small set of evaluators examines the user interface and provides opinions regarding modifications to the interface (Usability.gov 2012). The results from such evaluations are usually used to modify the product before actual usability testing. The number of evaluators recommended for heuristic evaluation is five, with the exact number of evaluators dependent on the cost-benefit analysis (Nielsen, 1994). Usability is an important aspect in clinical software, as even a competent user can induce errors if the user interface is poorly designed (Zhang, et al. 2003). By addressing usability during the development process, it is anticipated that the end result will be a more user-friendly app. Details on tasks and procedure design are covered in section 3.4.3.

3.4.1.1 SUS Questionnaire

The System Usability Scale (SUS) was developed by John Brooke to assess overall usability of a system (Brooke 1996). SUS uses 10 items to gather subjective opinions from users (Table 2). Each item is presented to participants on a 5-point scale, ranging from 1 for ‘strongly disagree’ to 5 for ‘strongly agree’. A more recent study had found that SUS can also be used to assess two sub-factors - learnability and usability of a system (Lewis and Sauro, 2009). Items 1 and 4 in Table 2 correspond to learnability of the system and the remaining eight items correspond to its usability. In this study, the SUS was used to assess both learnability and usability.

3.4.2 Objective 2

The second objective of the study was to compare the perceptions of helpfulness between clinical documentation on the mobile tablet app and traditional paper chart. A comparison questionnaire (Appendix C) was used to record the participant's preference between the two methods.

Table 2: SUS Items

#	SUS Item
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

3.4.3 Tasks and Procedure Design

Each participant was provided a sample scenario for syncope (Appendix E). The participant was then asked to record their observations on the paper chart and the iPad app in a serial fashion. The order of use of paper and app was pre-selected (the same number of participants were asked to record in a particular order in order to minimize learning effects on the study results). Each participant was asked to complete subjective evaluations on usability as well as a questionnaire that compared their perceptions of the iPad and paper.

The step-by-step process for the study was as follows:

- In a face-to-face lab environment, each participant was given a brief explanation of the study by the author. The participant was then asked to read the information form about the study and sign a consent form.
- The participant was asked to fill out the profile form (Appendix A) to gather demographic information.
- If the participant was pre-selected to use
    - App first - the participant was given a short training session with the iPad app. The participant was then given an opportunity to do some simple tasks with the app using a simple clinical scenario (Appendix D). Once the participant was comfortable with using the app, a complex clinical scenario (Appendix E) was provided. The participant was asked to record his or her evaluation of the given scenario on the app. The participant also had to complete a SUS usability questionnaire (Appendix B). For the second part of the study, the participant recorded his or her evaluation of the complex clinical scenario on a paper chart (Appendix F). The participant was also

asked to provide the most likely differential diagnosis after using each method.

- Paper chart first - he or she had to record the clinical evaluation of the complex scenario (Appendix E) on the paper chart (Appendix F) and provide the most likely differential diagnosis before using the app. For the second part of the study, the participant was given a short training exercise with the iPad app. He or she was then given an opportunity to do some simple tasks with the app using a simple clinical scenario (Appendix D). Once the participant was comfortable with using the app, the participant was asked to record the evaluation of the clinical scenario (Appendix E) on the app. Finally, the participant was asked to provide the most likely differential diagnosis.

- Participants were asked to complete a questionnaire (Appendix C) comparing the two methods.

During the study, each participant's interaction with the app was recorded programmatically. The time taken to complete each SOAP branch was also recorded. For the paper chart, the time taken to record the entire evaluation was recorded.

3.4.4 Data Collection

Data were collected from participants during the face-to-face study session. Each participant was given an evaluator identification number during the study session. Five types of data collected were during the study session:

a) Evaluator Profile (Appendix A) data included the evaluator's technical and clinical profiles.
b) SUS data were gathered from participants using the SUS questionnaire (Appendix B) immediately after using the mobile tablet app. The SUS score was calculated for each of the 10 items. The overall SUS score and sub-factor scores for usability and learnability were also calculated.
c) Timing data regarding user interaction with the mobile tablet app were collected programmatically. The timing data for paper documentation was tracked manually.
d) Comparison (Appendix C) data were obtained from participants after they had completed the documentation using paper and the tablet.
e) Clinical data consisting of history and physical examination findings were recorded by participants on the paper chart as well as the tablet. The participants also provided a differential diagnosis after using each method.

The author reviewed the clinical data recorded using both methods. The clinical scenario provided during the study had at least one factor to be entered in history of present illness, family history and physical exam findings. The scenario did not have any factor pertaining to past medical history. The vital statistics recorded in the app were also studied for factual errors.

Only evaluator identifiers were used to label the data collected. The sum, mean and median for time taken to record the clinical documentation were calculated for both methods. The overall SUS score and sub-factor scores for usability and learnability were also calculated. The results are presented in Chapter 4.

4. RESULTS

4.1 Participant Profile

Three medical students and two residents participated in the study. Four of the participants were trained in Ontario. One participant was trained outside of Canada. Technical and clinical information were collected as part of participant profile. This information is listed in Table 3 and Table 4.

Table 3: Technical Profiles of Participants

#	Question on use of mobile technology	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
1	What is your level of experience in using mobile tablets (iPad, Playbook, Tab, etc.)?	Experienced	Experienced	Experienced	Little Experienced	Little Experienced
2	Do you own a smartphone (phone capable of downloading standalone apps)?	Yes	Yes	Yes	Yes	Yes
2.a	Smartphone make and model	Samsung Galaxy	LG Optimus 2X	iPhone 4	iPhone 4	iPhone 3
3	Do you own a tablet (iPad, Playbook, Tab, etc.)?	No	Yes	Yes	No	No
3.a	Tablet make and model	NA	iPad 1	iPad 3	NA	NA
4	Do you currently use smartphone for clinic and/or classroom related tasks?	Yes	No	Yes	Yes	Yes
5	Do you currently use mobile tablets for clinic and/or classroom related tasks?	Yes	No	Yes	No	No
6	Do you plan to use mobile tablets for clinic and/or classroom related tasks?	Yes	Yes	Yes	Yes	Yes

The clinical profile of the participants is listed in Table 4.

Table 4: Clinical Profile of Participants

#	Question on clinical background	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
7	What is your clinical background?	Resident	Medical Student (Year 1/2)	Resident	Medical Student (Year 3/4)	Fellow
8	Specialization (if applicable):	Internal Medicine	NA	Pediatrics	NA	Internal Medicine
9	What is your level of experience in evaluating patients with syncope?	Experienced	Little experienced	Little Experienced	Little Experienced	Experienced

4.2 Timing Data

During information documentation, participants spent an average 325 seconds with paper and 588 seconds with the tablet (Table 5).

Table 5: Total Time Taken for Clinical Evaluations

Method	Mean (seconds) (n=5)	Median (seconds) (n=5)
Tablet	325	255
Paper Chart	588	600
Tablet used first	398	449
Paper used first	690	690

Table used second	216	216
Paper used second	520	480

Time to record patient information on the tablet varied for each SOAP category (Table 6). Participants spent more time recording the history of present illness (mean = 104 seconds) and the least time recording past medical history (mean = 15 seconds)

Table 6: Time Taken to Record Patient Information on the Tablet

Findings	**Mean (seconds) (n=5)**	**Median (seconds) (n=5)**
History of Present Illness	104	53
Past Medical History	15	13
Family History	89	78
Physical Examination	61	71
Total	270	176

4.3 Structured and Unstructured Documentation

All of the study participants used structured notes for documentation with the tablet. Only three of the participants used the unstructured 'Notes' section for documentation. The frequency of access to the 'Notes' section in given in Fig. 4.

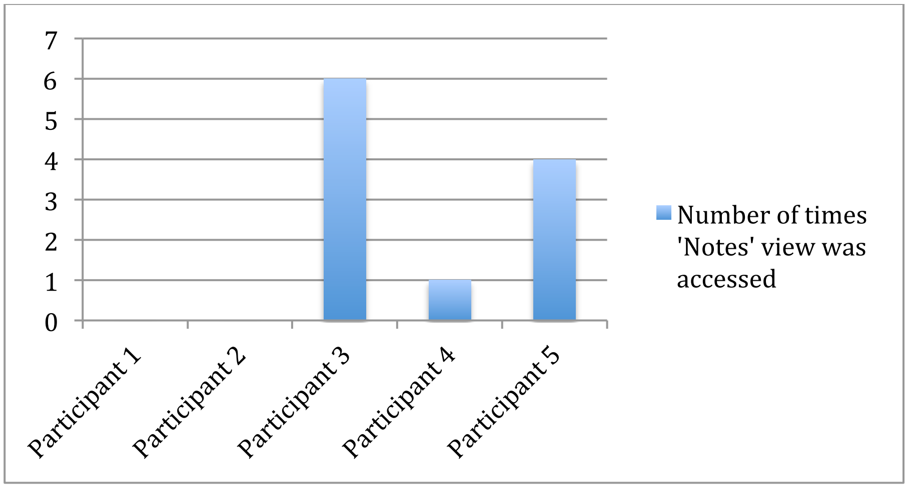

Figure 4: Frequency of Access to Notes section

4.4 Clinical Data

For the tablet, all the study participants recorded at least one entry in history of present illness, family history and physical exam findings. Four participants recorded 'syncope' in history of present illness and one participant recorded 'syncope' in past medical history. Two participants recorded detailed history of present illness in free-text. One participant recorded information pertaining to family history in free-text. All participants recorded physical examination findings and orthostatic vitals from the given scenario in the app. There were no data entry errors for vital statistics entries.

For the paper chart, all the study participants recorded information in the structured SOAP format. All the participants recorded detailed history of the present illness and family history on paper. One participant indicated that there was no past medical history, three participants did not record any information on past medical history, and one participant recorded 'syncope' in past medical history. All participants recorded physical examination findings and orthostatic vitals in the scenario.

The differential diagnosis recorded by each participant was the same for both tablet and paper. The three participants who had little experience with syncope evaluation recorded 'vasovagal syncope' as the differential diagnosis. Among the two participants with prior experience in syncope evaluation, one participant recorded vasovagal syncope (with follow-up by cardiologist) and the other participant recorded cardiac syncope as the differential diagnosis. Considering the complexity of the clinical scenario the diagnosis from the two experienced participants can be considered correct.

4.5 SUS Score

Each participant completed a modified SUS usability questionnaire (Appendix B) immediately after using the tablet.

The total score was calculated and the SUS score (Table 7) was determined as discussed in section 3.4. The frequency distribution of scores for each SUS item is given in Fig. 5.

Table 7: SUS Scores for Tablet

#	ITEM	Mean (n =5)	Median (n=5)
1	I think I would like to use this application frequently	2.6	3
2	I found the application unnecessarily complex	3.2	3
3	I thought the application was easy to use	3.6	4
4	I think I would need Tech Support help to use this application	3.8	4
5	I found the various functions in the application to be well integrated	2.6	3
6	I thought there was too much inconsistency in this application	3.2	3
7	I believe that most people would learn to use this application very quickly	3.6	4
8	I found the application very cumbersome to use	3.2	3
9	I felt very confident in using the application	2.8	3
10	I need to learn a lot about this application before I could effectively use it	3	3
	Total Score	31.6	31
	SUS Score	**79**	**77.5**

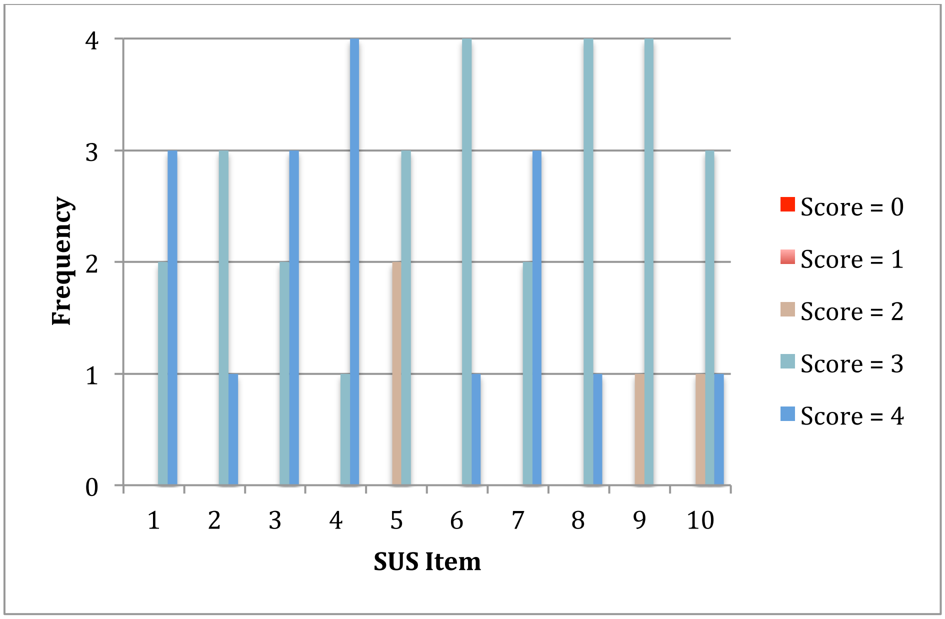

Figure 5: Frequency Distribution of SUS Scores for Tablet

The scores pertaining to usability and learnability sub-scales are given in Table 8.

Table 8: Learnability and Usability Scores

SUS #	Sub-scale	Mean	Median
1,4	Learnability	3.2	3
2,3,5,6,7,8,9,10	Usability	3.15	3

4.6 Overall Comparison

An overall comparison of usability between the two methods is given below:

Table 9: Overall Comparison

#	Item	Participants who prefer Mobile Tablet	Participants who prefer Paper Chart
1	Like to use this method frequently	3	2
2	Unnecessarily complex method	1	4
3	Easy to use method	3	2
4	Helpful in documenting patient history	2	3
5	Clinically relevant content	2	3
6	Too much inconsistency in this method	2	3
7	Most people can learn this quickly	4	1
8	Method was cumbersome to use	2	3
9	Very confident in using this method	0	5
10	Need to learn a lot about this method before I could effectively use it	3	2
11	Overall method comparison	1	4

5. DISCUSSION

Three participants in this study were experienced tablet users. Among the five participants, two were 'experienced' in syncope evaluation and three had 'little experience' in syncope evaluation. Four out of five participants spent more time recording clinical information on paper than on the tablet. This finding is in agreement with a study that reviewed randomized controlled trials that compared handheld computers and paper and pencil methods for self-recording and reporting data in clinical research (Lane, et al. 2006). The study reported that hand-held computers appear faster than paper and pencil methods of data recording.

Participants recorded a majority of the data in a structured format. Users recorded information on the app by tapping the item list provided within a SOAP branch. Even though free-text unstructured data were supported and prominently displayed on the app, only two users recorded elaborate free-text notes. This finding is consistent with the study conducted in an internal medicine training program (Zheng, et al. 2009). The study reported that residents rarely used a 'memo' field that was included as a critical feature by user representatives in the design team. Overall, participants recorded more narrative information on paper than with the tablet. A recent study among medical residents also backs up this finding by reporting the difficulty in note taking using iPads (Tanaka, Hawrylyshyn and Macario 2012) and handheld computers (McAlearney, Schweikhart and Medow 2004). A recent survey among 7500 consumers across the US, UK, France, Germany and Japan indicated that tablets are used more for content creation than notebooks and desktops (Morgan Stanley Research 2012).

Participants with prior experience in syncope indicated the correct plan of action for the given scenario. Participants with little experience in syncope evaluation failed to take into consideration the cardiac risk factors in the scenario. There was no change in the diagnosis recorded by participants after using tablet and paper. The app developed for the study supported clinical documentation and not clinical decision-making. An earlier study has shown that, even after computerized decision support consultations, attending physicians, residents and medical students showed no significant change in diagnostic judgments (Wolf, et al. 1997). However, a systematic review of the effects of computerized clinical decision support systems (CDSSs) on practitioner performance and patient outcomes, found that many CDSSs improved practitioner performance (Hemens, et al. 2011; Nieuwlaat, et al. 2011; Roshanov, Misra, et al. 2011; Roshanov, You, et al. 2011; Sahota, et al. 2011; Souza, et al. 2011)

There was no significant difference in the documentation recorded on tablet and paper. This outcome is different than the randomized controlled trial that compared handheld computer and paper chart documentation in the orthopedic ward of an academic hospital (Stengel, et al. 2004). The study found that documentation quality ratings for patient history and physical examination improved significantly with the introduction of handheld computers. One possible reason for the difference in outcome is that this thesis study used the same patient scenario for documentation on paper and tablet.

A SUS score above 68 is considered above average (Sauro 2011). The app scored an above average SUS score of 79. This could be attributed to usability considerations during the design and development of the app. The mean learnability and usability sub-factor scores for the app were 3.2 and 3.15 respectively (on a scale for values from 0 to 4, with 4 being the most positive response). The app was perceived as usable and easy to learn.

Participants preferred paper over the app in the overall comparison. One explanation for this ranking is that, unlike paper, the app required participants to navigate a SOAP branch to enter clinical documentation. Cognitive analytic methods could have been used to identify pertinent sections of the paper chart (Sharda, Das and Patel 2003); these pertinent sections could then be presented to the user in the initial app view. Furthermore, psychometric methods could be used to discover form-based characteristics of clinical documentation that can be used to evaluate quality of electronic clinical notes versus paper notes (Stetson, et al. 2008). However, such techniques were beyond the scope of this research.

5.1 Future Work

This study was limited to considering usability heuristics and interface design guidelines during app development. Further expansion of the research to include cognitive analytic methods to study paper charts can give further insight into core sections of documentation that are most helpful to users. The interface could then be re-designed to include these core sections. Additionally, psychometric methods and hierarchical task analysis could be conducted among experienced residents to improve clinical documentation using tablets.

A more advanced study of interoperability could integrate the app with the organization's EMR, enabling users to enter data directly into the EMR, and improving overall efficiency of the tablet application. In addition, accessing patient clinical records stored on the EMR system could reduce delays in patient care, eliminate the need to enter duplicate information and reduce inaccuracies in diagnosis (Archer and Cocosila 2009).

The present research used a usability questionnaire and clinical data to compare tablet and paper documentation processes. Further studies are required to determine whether a mobile tablet app is a qualitative improvement over clinical documentation with paper.

5.2 Conclusion

Mobile tablets are popular in clinical practice and medical education. The objectives of this study were to develop an evidence-based mobile tablet app for syncope evaluation and to understand the role of usability in perceived helpfulness of users.

This study showed that an evidence-based app can be developed, with emphasis to usability during design and development. The app facilitated structured documentation in standard SOAP format as well as unstructured free-text documentation. The usability study with medical students and residents revealed that the app had above-average usability, and users preferred structured data entry to unstructured data entry. The study revealed that additional factors such as cognitive analysis and psychometric methods must be addressed during app design and development. Further studies are needed to determine the level of detail of clinical information to be presented in mobile tablet apps.

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APPENDIX A: Evaluator Profile Form

1. What is your clinical background?
___ Medical Student (year 1- year2)
___ Medical Student (year 3 - year4)
___ Resident
___ Fellow
___ Attending physician
Specify specialty (if applicable) ____________

2. What is your level of experience in evaluating patients with syncope?
___ No experience
___ Little experience
___ Experienced
___ Very experienced

3. What is your level of experience in using tablets (iPad, Playbook, Tab, etc.)?
___ No experience
___ Little experience
___ Experienced
___ Very experienced

4. Do you own a smartphone (phone capable of downloading standalone apps)?
___ Yes
___ No
If Yes, what make and model is ?____

5. Do you own a tablet (iPad, Playbook, Tab, etc.)?
___ Yes
___ No
If Yes, what make and model is it? ____

6. Do you currently use smartphone for clinic and/or classroom related tasks?
___ Yes ___ No

7. Do you currently use mobile tablets for clinic and/or classroom related tasks?
___ Yes ___ No

8. Do you plan to use mobile tablets for clinic and/or classroom related tasks?
___ Yes ___ No

APPENDIX B: SUS Usability Form

		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					

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

APPENDIX C: Comparison Questionnaire

Evaluator No: _____

Insert 1 for Most Preferred, 2 for Least Preferred in each of the two columns

		Paper	App
1	I think I would like to use this method frequently		
2	I found this method unnecessarily complex		
3	I thought this method was easy to use		
4	I thought this method was helpful in documenting patient history		
5	I found this method provided clinically relevant content		
6	I thought there was too much inconsistency in this method		
7	I believe that most people would learn to use this method very quickly		
8	I found this method very cumbersome to use		
9	I felt very confident in using this method		
10	I need to learn a lot about this method before I could effectively use it		
11	Overall method comparison		

APPENDIX D: Clinical Scenario for Training

Martin is a cheerful 13 year old. He was playing in his backyard when he felt dizzy and collapsed on the grass. He felt nausea afterwards. He had no past medical history. His mother has a history of cardiomyopathy. There is no other family history of cardiovascular problems.

On physical examination, Martin looks well. His weight is 53.9 kg and his height is 164.5 cm. His orthostatic vitals include a heart rate supine of 55 bpm with a blood pressure of 113/62-69 mmHg. Sitting, his heart rate is 62 with a blood pressure of 135/71 mmHg.

APPENDIX E: Clinical Scenario for Testing

Lauren 14 y old had a syncopal episode in early November 2011. She is a very athletic girl, and at this time, was sprint training and had done approximately four cycles of 20 seconds sprints followed by 40 seconds rest. She had stopped for approximately 30 seconds when she felt darkness coming over her eyes and presyncope for "split second, " which was then followed by approximately five to 10 seconds of syncope. She had no chest pain, palpitations or diaphoresis associated with the episode. When she regained consciousness, after approximately five to 10 seconds, she was a little disoriented, but was otherwise asymptomatic.

The full pedigree was done and is in Lauren's chart. She has two older brothers and one younger sister who are all healthy. Her father has no medical problems and her mother has a history of cavernous hemangioma that was resected. Interestingly, there was a maternal uncle who died in the year 2000 unexpectedly at 50 years old while on the golf course. Apparently, he had no symptoms prior to this including chest pains or presyncope, and no postmortem was done. Her parents are not aware if there was a coroner's investigation and do not believe that there was any ECGs or echos done on this uncle's children. Maternal grandparents have a history of coronary artery disease.

From the paternal history, Lauren's father has five brothers and one sister. One of his brother's children has a history of syncope in his mid teens that was investigated fully including ECGs and echos and to their knowledge, there were no abnormalities identified. There was no pattern to the syncope and the conclusion from the family's perspective was that he is anxious and possibly associated with that. He has not had any recent syncopal episodes.

Other than the sudden death in the maternal great uncle, there is no other history of sudden death in the family including death while asleep or with sudden noises. There is no unexplained seizure disorders in the family. There is no other history typical for arrhythmia in the family.

On physical examination, Lauren is a pleasant young woman who looks well. On cardiac exam, she had an S1, S2 with no S3 or S4. She had a soft grade 1-2 systolic murmur that was heard in the left lower sternal border while supine that dissipated on inspiration, and while standing, she had a grade 1-2 murmurs heard in the left upper sterna border that decreased when she squatted. On respiratory exam, she had normal air entry bilaterally. She had strong pulses peripherally with no visible edema.

Her weight was 47.5 kg and her height was 153 cm. Her orthostatic vitals included a heart rate supine 55 bpm with a blood pressure of 113/62-69 mmHg. When she went directly from lying to standing after a minute, her heart rate went to 67 bpm with a blood pressure of 117/74 mmHg .

APPENDIX F: Paper Chart

Clinical Evaluation Form

WELLCARE HOSPITAL			
Acc#: P5670034	**Visit Date:** May 2012	**Visit Type:** New Referral	**Patient Name:** SMITH, LAUREN
Clinic: WH-PED-CAR **Family Physician:** **Attending Provider:**			**Address:** 1234 Main Street West Hamilton, Ontario
ALLERGY/ MED ALERT: None			**CURRENT DRUGS:** None

Doctor's Evaluation: