A Handheld Decision Support System for Cardiac Teletriage: Design and Evaluation

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Abstract

A gap exists in cardiac care between known best practices and the actual level of care administered. To help bridge this gap, a proof of concept interface for a PDA-based decision support system (DSS) was designed for cardiac care nurses engaged in teletriage. This interface was developed through a user-centered design process. Quality of assessment, quality of recommendations, and number of questions asked were measured. Cardiac floor nurses' assessment quality performance, but not their recommendation quality performance, improved with the DSS. Nurses asked more questions with the DSS than without it, and these additional questions were predominantly classifiable as essential or beneficial to a good assessment. The average participant satisfaction score with the DSS was above neutral. A new type of diagram was developed to map workflows during user needs assessment, and to help bridge the gap between hierarchical task analysis and interface design. Design recommendations for the DSS are offered.

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Introduction

As the number of Canadian cardiac patients increases, and the length of hospital stay decreases, there is a need for expert care and evaluation once patients return home from the hospital. The current services of homecare agencies, community hospitals, and family physicians are inadequate to meet the needs of this growing patient base for two main reasons:

(1) inadequate access to professionals (many patients may have to wait several weeks before seeing their family physician once they leave hospital) (Schoen et al. 2005) and

(2) limited professional access to up-to-date, best practice guidelines for cardiac care (Momtahan, 2004).

The Nursing Coordinators (NCs) at the University of Ottawa Heart Institute (UOHI) receive more than 1500 calls per year from patients requesting help and advice for cardiology and cardiac surgery concerns. Though teletriage is significant in the care of these patients, there is no standardized protocol in place to guide the advice-giving, and nor is there any formal training for staff.

The purpose of this thesis is to design an effective Decision Support System (DSS) to help primary healthcare professionals field these calls. The final DSS will initially be used by the NCs, but aims to assist less experienced care providers in the future. The literature suggests that challenges lie both in the practice of teletriage (Briggs, 2003; Bunn et al, 2004; Lowery, 2001; Wheeler, 1993), and also in the design and development of decision support systems (Braden et al, 1997; Fischer et al, 2003;

Hastings, 2001; Rodriguez et al, 2004; Rosenbloom et al, 2001). To the extent that an inadequate design may rest on poorly defined user tasks, one would expect improved DSSs to result if that limitation were to be overcome. This thesis will therefore explore the use of task analysis as part of a user centered design process aiming to produce an effective DSS.

The User Centered Design Process

In the context of software development, user centered design (UCD) is an approach that focuses on making products usable. Usability relates to the interaction quality between the user of the product, and the software application itself (Daly-Jones, Bevan, Thomas, 1997). Usability is defined in this circumstance 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" (Daly-Jones et al, 1997; ISO, 1997). Fundamentally, the process includes the identification of user and/or business needs, design, and evaluation. This process is iterative, and in the best cases proceeds in cycles of assessment, design, and evaluation until the optimum final product is achieved – or until business needs require the product to be shipped.

Preliminary data gathering begins the needs assessment phase. The purpose of this step is to determine requirements and constraints for the system. Facets of this stage include determination of user needs, current workflow, and constraints. Many stakeholders, each with their own requirements for and interest in the system, may be considered during this phase. Examples of stakeholders in the UOHI DSS include NCs, patients, cardiologists and cardiac surgeons, DSS developers, and the UOHI information technology staff.

Prior to starting the design phase, the designer must understand the problem clearly and define it carefully, isolating principal parts of the problem (Wright, 1999). The problem in this case is that NCs do not have access to cardiac best practices for teletriage. The solution lies in carefully considering how the NCs currently assess patients via telephone, and to integrate cardiac best practices in a way that improves the experience for NC and patient alike. To help define the problem space, designers and researchers use methods such as task analysis, cognitive task analysis, or cognitive work analysis. These will be described in more detail later.

As design commences, the designer should strive to generate as many ideas as possible while avoiding initial judgment (Kelley et al, 2000). Once this is done, the designer preserves strong ideas and rejects weak ones by carefully weighing benefits and drawbacks of each concept. The designer selects those ideas most likely to lead to an acceptable solution, ensuring that the solution fully solves the problem.

Another part of the user centered design process is evaluation. Broadly, there are two types of user interface evaluation: formative – which helps guide the design as it is being developed, and summative – which tests the usability of a completed design (Industry Usability Reporting project, 1999). Formative evaluation can and should occur early in the process, where it may first appear as an informal critique of ideas on paper. Usability testing represents more formal evaluation, and can be either formative or summative. Usability testing can generally begin once a prototype is robust enough to mimic functionality of at least a few tasks. Nielsen (2003) suggests that formative testing of paper prototypes is particularly useful, as the designer receives the feedback they need on the interface without a large expenditure in time and coding resources.

Time constraints, budget restrictions, or lack of access to end users or appropriate surrogates, can cause designers and developers to take shortcuts. Developers might feel time-pressured to start coding the product right away, rather than create throw-away prototypes for formative evaluation. Project teams may feel similarly pressured in time and resources, and might decide that if they can only test once, they will reserve usability testing for the final step to validate the product. However, changes to the interface are far cheaper when they occur during the early prototyping stages, rather than after the product has been formally coded and is ready for release (Nielsen, 2003). This underscores the importance of both early prototype development and of formative evaluation in a successful UCD process.

Systems such as the UOHI DSS are risky on a number of levels, and careful preliminary investigation prior to design can help mitigate these risks. For example, it is a very specialized system used by a group of specialist users. These users currently work from memory using a very simple pen and paper checklist. The DSS introduces new protocols for assessment, as well as introducing new technology in this context. Taken together, these increase the burden on the practitioner's attention when on the phone with a patient. Additional risk exists in long-term use of the DSS, as best practice protocols could change and necessitate an update of the system. Though the current work procedure and conditions are investigated, a more detailed risk analysis is outside the scope of this research.

Task Analysis in UCD: Constraint-Based, or Traditional?

The purpose of task analysis in UCD is to gain insight into how users do their work, allowing other parts of the UCD process to be used to greatest benefit (Shepherd, 2001). Different methods of task analysis focus on different aspects of how users work. Some focus on the series of actions, some on decisions, some on the knowledge the user brings to the task itself. Task analysis benefits the user centered design process by giving the designer insight into how users presently accomplish a task. The main drawback of this type of analysis is that it describes present rather than future task behaviour. This weakness is addressed in this thesis by including a set of theoretical best practices, which describe ideal behaviour, in the input for the task analysis.

There are two major categories of task analysis: constraint-based and traditional. Cognitive task analysis and cognitive work analysis are examples of constraint-based frameworks. Naturalistic decision making, decision-action analysis, and hierarchical task analysis are examples of traditional frameworks. Each of these is reviewed here, and a framework is selected for task analysis in this study.

Cognitive Task Analysis (CTA)

The first constraint-based approach is cognitive task analysis (CTA). Chipman, Schraagen, and Shalin (2000) describe Cognitive Task Analysis (CTA) as "the extension of traditional task analysis techniques to yield information about the knowledge, thought processes, and goal structures that underlie observable task performance." This method is considered here because Seamster et al (2000) suggest that CTA lends itself to supporting the design of job aids and training systems, which describes the design scenario for the UOHI DSS.

CTA consists of three main phases: (1) preliminary phase; (2) identifying knowledge representations; and (3) eliciting knowledge. In the preliminary phase, referred to as "bootstrapping" (Chipman et al, 2000) or "table-top analysis" (Flach, 2000), the researcher becomes familiar with the worker's job and associated tasks, and learns any special vocabulary associated with it. This phase includes determining functional and information constraints. The next step for the researcher is to identify the "abstract nature of the knowledge involved in the task" (Chipman et al, 2000). The goal of this phase is to determine a general framework for the knowledge that will be gathered from workers in the next stage. Finally, the researcher elicits knowledge from expert workers. There are a number of techniques to accomplish this, including structured interviews, observation of expert performance, observation of apprenticeship training, and using think-aloud protocols while SMEs (Subject Matter Experts) perform the tasks being analyzed.

With the exception of carefully administered interviews, these techniques are not viable for the UOHI DSS project. Direct observation of tasks would violate patient confidentiality. Additionally, Shryane et al (2000) suggest that although direct observation can reveal facets of task performance that may not come to light through interviews or documentation, a significant weakness is the "observer effect", which is likely to affect the worker's task performance. There were no new NCs hired during the preliminary phase of this thesis, which made observation of apprenticeship training impossible. There is also no formal apprenticeship procedure for training new NCs to handle patient phone calls. Think-aloud protocols weren't feasible, as the tasks themselves require the NC to speak.

Seamster et al (2000) recommend CTA for environments where there are significant cognitive demands on the workers and where "time-constrained decisions are critical to overall performance" (p. 135). The decisions in the UOHI teletriage system are not time-constrained, in that the NCs and patients are free to continue their telephone dialogue until communication at both ends concludes in a mutually satisfactory way. However, the patient's problem must be assessed and a decision reached as quickly as possible – if the patient is in distress, it could prove fatal if immediate medical help is not provided. Cognitive demands could be less with the DSS in place than in the current situation, since the NCs will receive assessment guidance from the handheld device while they are on the telephone. In the present scenario, the NC must rely on their memory and experience.

A problem in CTA is that it is often unclear how to apply the products of cognitive task analysis to the design of a system interface (Chipman, 2000). Other forms of task analysis, such as hierarchical task analysis and decision-action analysis, produce concrete products that can be applied more directly to problems like user interface design.

Because the cognitive demands on the workers are moderate, the decisions critical to overall performance are not tightly time-constrained, and because its products do not directly support interface design, CTA does not appear to be the best fit as a task analysis method for the DSS. It is rejected for this research, and not discussed further.

Cognitive Work Analysis (CWA)

Cognitive work analysis (CWA) analyzes both environmental and cognitive constraints in a work system, "as a means to derive implications for design" (Vicente, 2000, pg. 2). This method gives first priority to determining environmental constraints, and then analyzes cognitive constraints to close "the remaining degrees of freedom for action" (Vicente, 2000, pg. 58). CWA consists of five phases, sequentially analyzing (1) work domain; (2) control tasks; (3) strategies; (4) socio-organizational factors; and (5) worker competencies.

Vicente (2000) stresses that CWA is best suited to complex sociotechnical systems. In his comparison of CTA and CWA, he criticizes task analysis, even those methods that are constraint-based such as CTA, as requiring an initiating event or task to be analyzed. This, he argues, does not adequately provide for situations where unexpected events occur in a complex sociotechnical system. To determine the suitability of CWA, the present situation is assessed against the criteria for such a system.

Is This a Complex Sociotechnical System?

What makes a system complex? According to Vicente's (1999) description of a complex sociotechnical system, we find the following:

Parameter	Example	Applies to the UOHI DSS
Large problem spaces	trying to distinguish/diagnose among 500,000 identified illnesses	No
Social	communication between many different workers must be effective for the system to succeed	No
Heterogeneous perspectives	workers are from widely different backgrounds, and hold potentially conflicting values or ideas	No
Distributed	where there is significant geographic separation between decision-makers	No
Dynamic	It can take a long time for the work domain to respond to an action on the part of the worker	No
Large potential hazard	Catastrophic consequences	No
Coupling	many interacting subsystems make if difficult to trace all implications of a disturbance	No
Automation	the system itself is highly automated	No
Uncertainty	in the available data	Yes
Mediated interaction	the goal-relevant properties of a system cannot be directly observed	Yes
Disturbances	there exists disruption to normal work procedure by unanticipated events	Somewhat

Table 1: Parameters of a Complex Sociotechnical System

The present telepractice system rates highly on mediated interaction, and on possible uncertainty in the available data. A telephone call is, by nature, a mediated interaction, as the parties are not communicating face to face. Disturbances are also to be expected in the NCs' working environment, but these would not be considered probable cause of system failure. The perceived (self-reported) effects of both these factors were determined in interviews with the NCs.

Uncertainty in the data, or information in the present case, could originate from three places in the system. First, the NC might be unsure that the patient is giving them accurate information about their symptoms. Second, the patient may not be certain that the instructions being given to them by the NCs are the best for their situation. Lastly, the NC might be unsure that the PDA is giving them the best information possible for their patient. However, because the information obtained from the PDA comes from best practice algorithms created in coordination with the NCs themselves in the present case, the NCs are highly likely to be confident in the best practices guidelines. These algorithms will be discussed later in more detail.

The UOHI DSS does not rate highly on Vicente's other parameters for a complex sociotechnical system. The problem space is satisfactorily defined, as we are dealing specifically with calls from cardiac surgery or cardiology patients.

From a social standpoint, the NCs naturally work in harmony with physicians and other staff to provide the best care for patients. But during patient phone calls, NCs work autonomously. So the complex social nature of a hospital work environment does not translate directly to our specific NC-patient call situation. Likewise, heterogeneous perspectives become less of an issue due to the autonomy of the NCs in this particular task.

There is sometimes a geographical separation between the NC and patient, as some patients travel quite a distance to be seen at the UOHI. However, since their communication is already mediated by the telephone, one would not expect the additional geographic separation to contribute significantly to any system failure.

Vicente describes "catastrophic consequences" such as nuclear meltdown, where a mistake causing system failure is likely to kill many people and also have lasting, widespread environmental effects. While system failure (i.e. the patient receiving and acting on incorrect information from the NC) could result in problems for the patient as well as professional sanctions against the NC, this does not fit Vicente's particular definition of "catastrophic."

Vicente's issue of coupling, where many interacting subsystems make it difficult to trace the effects of a disturbance, is not a problem in this situation. Figure 1 shows the most basic subsystems in the interaction of a patient-to-NC phone call, including the proposed DSS (shown as "Best Practices on PDA"). It is clear that the number of subsystems is limited; they are not expected to pose a problem of complexity.

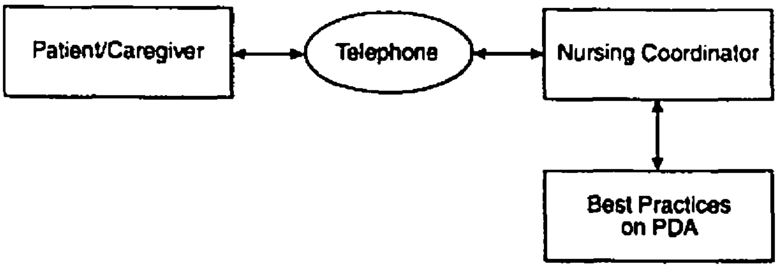


Figure 1: Phone call between patient and nursing coordinator, basic interactions

From the above analysis it appears that though our system uses mediated interaction and there is potential uncertainty in the data, it does not rate highly on most of the other criteria Vicente lays out for a complex sociotechnical system (see Table 1). Although a basic review of environmental constraints is desirable as a foundation for performing task analysis, a full-fledged cognitive work analysis does not appear to fit the needs of this system.

Traditional TA Approaches

From the above discussion, it is evident that CTA and CWA are not a good fit in informing the design of this DSS. Traditional task analysis outcomes are more descriptive, and more directly applicable to the design process, than products of constraint-based approaches. The nature of these users' work also makes extended observation and analysis impractical, primarily due to privacy concerns, but also because these activities can be intrusive in a busy medical environment. Another factor that makes such observations challenging, is the difficulty in predicting when teletriage calls will be received.

Though champions for both constraint-based and traditional task analysis dwell primarily on the limitations of the other, these techniques are not entirely mutually exclusive. For example, context and constraints are considered during hierarchical task analysis (HTA) (Shepherd, 2001). HTA includes exploration of design constraints, as well as constraints within the user's environment, constraints on available options for the analyst/researcher, and other factors that may need to be observed.

There are many varieties of traditional task analysis, each one best applicable to a certain kind of system and associated task. Naturalistic decision making, decision-action analysis, and hierarchical task analysis are assessed below.

Naturalistic Decision Making

Naturalistic decision making is a task analysis technique that focuses on decisions users make, rather than on elucidating plans and goals. It is described as "the way people use their experience to make decisions in field settings" (Zsambok, 1997). Rather than endeavoring to improve the way users make decisions, NDM describes what they currently do (Klein, 1997). Though this technique is strong in evaluating context, its focus on "situation awareness" and on how expert users make decisions may cause other critical parts of the total process to be neglected (Howell, 1997). The introduction of best practices in a DSS could also change the way NCs make decisions during teletriage. While this difference in decision-making strategy might be interesting for future study, it is not the focus of this thesis.

Decision-Action Analysis

Decision-action analysis is often used in software development, and is best suited for simple binary decisions such as "yes/no" (Chapanis, 1996). However, certain aspects of a patient call will not be binary in nature. For instance, the primary complaint may range from being generally unwell to very localized and specific chest pain, requiring the NC to choose from a long list of presenting symptoms. The NC might ask the patient to rate their pain on a scale from 0 to 10 – again, not a binary choice. Details around the patient's complaint can be qualitative – for example, a description of pain as sharp, dull, or aching. The pain may be in multiple locations, such as the chest, neck, back, or arm. Depending on the patient's responses, the flow of questioning may change. Perhaps the NC suspects that the cardiac surgery patient's incision might be infected, and they probe for more details to be sure. Decision-action diagrams are linear in their layout and progression, but the tasks in the present teletriage system do not appear to be a natural fit.

Even though some binary (yes/no) decisions are present in the algorithms developed for the present thesis, the tasks that must be accomplished during a phone call appear to have a definite hierarchy. For example, assessing a patient can be broken down into determining the primary complaint, getting the patient's recent treatment history, probing for details on the patient's discomfort, and determining the care required. The task of probing for pain details breaks down further into its own subtasks. This suggests that the most suitable way to look at the kinds of tasks here is through some kind of hierarchy, rather than via the strict linear flow of a decision-action analysis.

Hierarchical Task Analysis

Hierarchical task analysis (HTA) is one of the most frequently used techniques for task analysis (Miller and Vicente, 2001; Richardson et al, 1998). HTA is a record of a process, which conceptualizes tasks as a series of subgoals and associated plans. The goals illustrate what a person is expected to achieve at each step, and the plans describe the conditions in which subordinate goals should be carried out (Shepherd, 2001).

Shepherd (2001) identifies three main considerations in a hierarchical task analysis: (1) judging which parts of the task merit investigation; (2) for critical parts of the task, ascertaining what factors cause user performance problems, and determining what can be done to solve these problems; and (3) where subgoals must be carried out to meet the overall objective, redescribing operations into subgoals and their associated plans. Shepherd (2001) suggests a number of areas in which constraints should be explored during a hierarchical task analysis:

- constraints on available options for the analyst (person doing the task analysis),
- constraints within the user's operating environment,
- design constraints (for example, small screen area on a PDA).

Other conditions may also warrant attention, for instance if a culture is present where people do not use job aids.

Sources of input for hierarchical tasks include direct task observation, documentation, and interviews. Direct observation is rejected due to patient privacy concerns, and because it is difficult to predict when a teletriage call might come in. Formal procedural or training documentation does not exist. However, a set of call templates (Appendix B) – completed by the NCs – document typical real-life phone call scenarios, and are available to help inform the task analysis. Interviews with experts are also a feasible source of information for task analysis input in this situation.

The product of this technique is an HTA diagram (see Appendix G), which should give a clear and concise visual description of the goals and plans. In their investigation of task analysis in the defense industry, Ainsworth et al (2000) found that in certain cases where a hierarchical task analysis had been reported, HTA diagrams were cluttered or even non-existent. To gain maximum benefit from this kind of analysis, HTA diagrams should be clear and easy to follow (Ainsworth et al, 2000). In addition to the use of these diagrams within the HTA framework, designers make design decisions by assembling a set of functional requirements and constraints, and making choices that comply with these.

Hierarchical task analysis is a well-rounded method of task analysis, in that it considers critical environmental and system constraints as well as the tasks at hand. It is not limited to describing a decision-making process, nor is it rigidly linear. It appears to be a good fit as a task analysis framework for the UOHI DSS.

From Task Analysis to Design Decisions

Task analysis helps designers understand what the user must accomplish, assisting in the creation of usable workflow and system interaction. However, the artifacts produced during task analysis, such as HTA diagrams, are somewhat abstract. For example, even though each step in a given task may be very well-defined, it is still descriptive of the overall goal at that level rather than the exact action for a given scenario. This creates a gap between the results of a task analysis and the actual design of an interface. The presence of a set of functional requirements and constraints helps inform the design, but at some point a designer still must decide exactly what goes into each screen and how the user will get there. In order to help bridge this gap between task analysis and design, it was necessary to create a novel kind of diagram representing the results of the task analysis in the context of the more focused, concrete flow of a particular scenario. This diagram will be discussed later.

Teletriage

Lafferty (2001) defines teletriage as the "assessment of a request for medical intervention for the purpose of ranking the level of medical intervention needed" (pg. 2). One could arguably trace the origin of teletriage back to the origin of the telephone itself (Wheeler, 1993). Alexander Graham Bell famously cried out for assistance following an accidental acid burn during the world's first telephone call (Wheeler, 1993). Granted, his assistant Watson, who was on the other end of the line, had no standardized protocol or training with which to guide Bell in treating his problem. But as it turns out, that is still a common failing in modern teletriage.

In addition to this lack of appropriate protocols, the literature suggests that medical staff are often inadequately trained and prepared to handle teletriage (Katz, 2001; Wheeler, 1993; Lowery, 2001). Though some learn informally on the job, Wheeler (1993) suggests that learning through experience and observation is inadequate, and that more formal training is required. Citing a study of emergency department staff by Levy et al (1980), Wheeler observes that these practitioners often failed to obtain baseline information from the patient, and frequently gave advice without obtaining adequate histories (1993). Citing a study by Katz, Pozen, & Mushlin (1978), Wheeler notes that where pediatric health assistants were specifically trained to handle calls, the need for office visits and home management was reduced for 30% of clients. A similar study by Fischer and Smith (1979), where no training had been done, saw a similar reduction for only 6% of clients. This suggests that, with formal training in teletriage, health care workers can effectively solve the patient's concern through the phone call itself, and reduce the need for time and resources from other healthcare professionals.

One of the challenges to teletriage is the fact that practitioners are forced to assess and advise patients without actually seeing them. They must rely completely on spoken communication; non-verbal cues normally present in an in-person assessment are lost. Combined with the fact that face-to-face interviewing skills may not transfer directly to telephone communication (Lowery, 2001), this can contribute to communication problems not faced when the nurse assesses the patient in person. A nurse's advice is also based on information provided by a non-expert – the patient. The patient may not know what is normal or abnormal, or what symptoms are critical to share with the nurse. The patient may also be too stressed or worried about their condition to communicate clearly. It is therefore imperative that the teletriage practitioner be able to ask the right questions, at the right time in the interaction, to probe for this information. In the case of cardiac patients, this assessment should be both effective and efficient, as the patient may be in acute distress requiring immediate medical intervention.

Teletriage is open to potential liability issues, which can affect the way calls are handled (Braden, 1997; Briggs, 2002). Wheeler (1993) points out that nurses are not permitted to diagnose by phone, and that rather than trying to determine what caused the symptoms, the telephone triage nurse must only identify symptoms and classify them according to potential seriousness. Patients should not be left with the impression that they have received a firm diagnosis (Wheeler, 1993). Poor documentation of telephone encounters can add to potential medical-legal problems if it is vague, incomplete, or fails to show adherence to protocols or show that proper advice was given (Briggs, 2002; Lafferty et al., 2001).

Despite these challenges, the use of telephone consultation and triage has grown: in their review of telephone consultation studies, Bunn et al (2004) found that, in general, at least half of all patient calls were resolved by telephone advice alone.

Teletriage at the UOHI

Teletriage at the UOHI is performed by the NCs. The phone line to the NCs is currently available to patients 24 hours a day, seven days a week. NCs take phone calls at varied locations around the UOHI building, and all advice and information they give is from their own memory. No documentation or manuals exist for either training or clinical use. NCs do use a Telepractice Documentation Record (Appendix A) which helps them document the call, but does not provide much in the way of guidance. New NCs are trained on the job by existing NC staff.

NCs' other duties, determined by their role to ensure the smooth running of clinical areas in the hospital, include in-patient triage, problem-solving unusual events, education and support for staff nurses, patients and patients' families, and other advanced practice activities such as conducting research and giving presentations. The NCs are generally the only nurses at the UOHI who assess and advise patients by phone. The floor nurses, though they are also specialized in cardiac care, refer callers to the NCs rather than remotely assessing or advising a patient themselves.

The patients calling the NCs have generally been treated at the UOHI. They are older, have complex co-morbidities, and must sometimes undergo re-operation. There are also an increasing number of valve surgery patients. The main instigating factors for cardiac surgery patient calls to the UOHI include "information needs" (20%), pain (15.3%), problems with medication (14.9%), incision concerns (14.2%), and shortness of breath (10.4%) (Stolarik et al, 2004). Information about instigating factors for calls from cardiology patients is not currently available. For simple information or medication questions, the patient may need only reassurance from the NC. Other callers may have symptoms that result in an instruction from the NC to call 911, visit the ER, or present themselves to the UOHI. The NC may also recommend that the patient try certain medications, such as Nitroglycerine or ibuprofen, to try to alleviate their discomfort before taking further action. This research focuses on pain complaints for cardiac surgery and cardiology patients.

Current technology for NCs is limited to a pager and regular telephones. Cellular phones are not used due to their potential for interference with hospital equipment.

Best Practices in Cardiac Care

The growing number of cardiac patients combined with the increasing use of patient telephone consultation suggests a need for an effective, standardized method of communicating best information to patients. A gap exists in cardiovascular care, due to a discrepancy between processes of care that are recognized as best practice and the care provided in the usual clinical practice (Tremblay et al, 2004). According to Tremblay et al, estimates indicate that "30% to 40% of patients fail to receive treatments of proven effectiveness, and 20% to 25% of patients may receive care that is not needed or is potentially harmful" (p. 1195). Translation of best evidence into best practice guidelines can help optimize care, and also assist in education and training for healthcare providers (Tremblay et al).

To standardize the communication of best information to UOHI patients and assist in training new NCs, best practices in the DSS will come from a series of algorithms generated specifically for this purpose. These best practice guidelines will be delivered to the NCs via a handheld computerized device, in a format that allows them easily to refer to it while speaking on the phone with a patient.

Handheld Decision Support Systems in Medicine

Computerized decision support systems "encompass any computer software employing a knowledge base (facts and/or rules) designed for use by a clinician involved in patient care, as a direct aid to clinical decision-making" (Braden, Corritore and McNees, 1997). In this research, we focus on a DSS delivered via a handheld device.

Existing Handheld Medical Applications

Handheld devices such as Personal Digital Assistants (PDAs) have been used in a number of existing medical systems. Current systems offer applications including decision support, education, and reference, as well as calculators and analysis tools. A number of small tools are offered free of charge online – these are generally presented enthusiastically as useful and up to date, but are often listed with hefty disclaimers to use "for information only," meaning that they are not to be relied on for clinical decision making. Other tools, usually commercially available at a small cost, are maintained for content accuracy and sold as suitable for field use. Another application identified in the literature for handheld medical DSSs is for military use (Hastings, 2001).

These systems are often highly specialized, offering features that would be used frequently by a targeted subset of the medical community such as paramedics or anesthesiologists. TheraDoc's AntibioticAssistant (TheraDoc Inc., 2004) is an example of a specialized decision support tool. It uses an algorithm to help physicians prescribe appropriate antibiotics based on patient characteristics, allergies, and mitigating conditions such as pregnancy. Another small and specialized system, CardioMath (Chow, 2005), contains over 50 formulae that are commonly used in cardiovascular medicine. The UOHI decision support tool falls into this highly specialized category. It is being developed specifically for cardiac teletriage.

Other systems, such as Dr. Kent E. Willyard's MedRules (Willyard, 2003), offer more general education. MedRules uses clinical prediction rules, drawn from evidence in the literature, to educate physicians on best practices for ailments ranging from acute sinusitis to urinary tract infection diagnosis. However, the author stops short of calling this tool a DSS, providing it freely as educational software rather than as a diagnostic tool. The author is no longer updating the system, and cautions that the algorithms may fall out of date. This is a consideration for any decision support tool using best practice algorithms.

Some developers offer customizable products, or systems that carry and share live data. An example of such a system is Iterum's eMedic (Iterum LLC, 2004), a decision support system for emergency medical services. eMedic's Palm tool offers assessment algorithms, calculators, and other emergency medicine tools. Rather than expecting all customers to use the same set of information, eMedic allows records in this application to be customized according to state, local, or agency requirements, and then shared with other team members running compatible hardware systems.

Handheld devices are being used increasingly in an administrative capacity in medicine, taking advantage of the PDA's ability to easily share and transfer data as well as the ability of physicians to carry it with them. For instance, PDAs can be used as a link between the physician and the electronic medical record. PDAs can also assist with prescriptions, from printing out an easily readable script to sending a direct electronic prescription to the pharmacy – thus reducing the likelihood of errors attributable to illegible handwritten scripts (American Academy of Family Physicians, 2005).

Operating Systems for Handheld Devices

In their review of handheld computing in medicine, Fischer et al (2003) compare the two main competing operating systems for PDAs: Windows CE (now called Pocket PC or Handheld PC) and Palm OS. From a usability standpoint, the Windows CE operating system was found to be more complex, attempting to fit a standard Windows interface into a smaller screen (p. 143). Palm OS, conversely, was found to be simpler to use, and was developed specifically to suit a PDA's smaller screen area. It is not stated how they assessed the usability of the two operating systems. The Palm OS is designed to run a limited number of tasks, and cannot run more than one program at a time. However, software development for this system is technically less demanding than development for Windows CE. Consequently, many more products for Palm OS are produced by independent developers.

Handheld DSS and User Performance

Johnston et al (1994) found strong evidence to suggest that certain computer-based clinical decision support systems can improve physician performance. Fischer et al (2003) found that the most active users of handheld devices in the medical community are physicians in small group practices outside hospitals, and that "handheld computers seem to be widely accepted in family practice residencies" (p. 146). In Hastings' study of a DSS examining crush injuries (2001), even novice PDA users quickly learned how to use the tool, and "overall comments about the system were very positive." These are positive signs that a handheld DSS for the UOHI could be successful, and well-received.

However, these systems are not without problems. Rosenbloom et al. (2001) noted that many PDA resources for medical applications are flawed because they are awkwardly converted from a book format, they are updated infrequently, and they are difficult to use. In the UOHI DSS, content will be recent and will be organized specifically for delivery on a handheld unit. However, ease of use is still a challenge.

Fischer et al (2003) and Rodriguez et al (2004) observed that a barrier for many people is the small onscreen keyboard or handwriting recognition system used for data entry. Hastings (2001) found that users preferred to use the onscreen keyboard over the Graffiti handwriting recognition feature, which they found distracting. UOHI DSS will use an onscreen keyboard where text entry is required.

Rodriguez, Borges, Soler, Murillo, and Sands (2004) found that though text entry on the PDA was slow, users were actually faster on a PDA than on a laptop with tasks requiring only point-click actions. This suggests that, particularly in the present case where the NC is attending to a telephone call at the same time as the PDA interface, text entry should be kept at a minimum and the majority of the interaction should be restricted to point-and-click actions.

In addition to the awkward text input modalities, the small screen is another key element of the PDA interface that can affect physician performance and user satisfaction (Rodriguez et al, 2004). During reading tasks in the Rodriguez study, smaller font size on the PDA and the necessity for the user to scroll resulted in longer task times on the PDA than on a laptop computer. This suggests that scrolling is undesirable in a PDA interface, requiring a design that breaks up large quantities of information and limits screen contents to only the most important elements at any given point.

Factors Essential to Success

Previous research suggests that essential parameters to the success of a teletriage and advice system include communication skills, training, documentation, and easy access to health information resources. Lafferty (2001) stresses the importance of having a standardized protocol, and evaluating the teletriage system for quality, accuracy, and consistency. The literature also suggests that certain components are critical to the success of a DSS: the technology, the software, the associated information systems, and the users themselves (Fischer et al, 2003). The hardware and software must be usable in the medical environment. Even given this, the user's interest in and acceptance of the tool could be the limiting factor that bars successful implementation of the new system (Fischer et al, 2003; Braden et al, 1997).

Even though it has been shown that usability and user acceptance are critical to the success of a computer based decision support system, there was no mention of a user centered design procedure in any of these studies, nor were any formal usability tests reported in the literature.

The UOHI DSS

The system being developed in this research for the UOHI will allow the user to download telephone records to a central repository. It will not carry live patient information or be associated with a patient database, as there is no such database available at the UOHI at this time. Any records saved for the call would have to be directly entered by the NC during or following the call. Records would consist of a summary list of symptoms and characteristics the NC checked off while speaking with the patient, as well as written notes or voice recordings to document the advice given by the NC and any follow-up action agreed upon with the patient or their family. All information fields on the currently used Telepractice Documentation Record (Appendix A) are available in the DSS, using electronic field types suited to the type of information being recorded.

PDAs were selected to carry the future UOHI DSS, because they are portable, fit into a lab coat pocket (unlike tablet computers), and they don't require cooperation from the IT department – the latter minimizes reliance on support outside of the user group, simplifying system deployment. The PDA is easily carried to a more private location to record voice notes, following conclusion of a call.

The Palm Tungsten T3, running the Palm OS, was chosen by the UOHI project team after careful consideration, as it allows the user to record voice memos, which the NCs indicated would be a welcome feature. The voice recording capability of the T3 was not evaluated in context with the prototype, but this functionality may eventually prove to be an important and effective replacement for long text entries normally required on the telepractice form. Cost was also a factor in choosing this particular model, as well as the fact that it runs the Palm operating system which has historically supported other medical applications. The T3 display area is also relatively large compared to other handheld units, and expandable via a slider at the bottom of the unit.

Arriving at an Effective Design for PDA-Mediated Best Practice Access

While there is evidence that PDA-use in a medical setting is on the rise (Fischer et al, 2003), the usability of computer-based decision support systems for medical practitioners has been called into question in a number of cases (Hetlevik et al, 2000;

Chang et al, 2003). There is strong evidence in the literature to suggest that usability of a DSS is a major factor in determining a system's success in a medical environment (Braden et al, 1997; Chang et al, 2003; Hastings, 2001).

For example, Braden et al (2001) state that the usability of a computerized decision support system is a factor influencing that system's success or failure (pg. 302). Braden et al (2001) further suggest that the challenge is to design a highly intuitive DSS interface, since the users are "primarily non-technical professionals with high domain knowledge but low technical expertise and little time." Finally, Braden et al (2001) conclude that "careful development which involves the users(s) in non-trivial ways at every step is one of the major keys to success." This supports the choice of a user-centered design process for the UOHI DSS.

Chang and Hetlevik bemoan the lack of interface quality and "user-friendliness" in the systems they tested, but neither study included a usability test of the device or its information contents. While quantitatively comparing user performance with and without the device may justify the use of a tool, it will not tell us if the tool will be accepted by the users, nor the reasons why or why not. Hastings (2001) concluded that it is necessary to develop an "optimal user interface" with users, thus employing a user centered design approach, but information on usability in the Hastings report was limited to informal observation. Nothing was mentioned about how the interface was designed and developed. Hastings did comment that users who were initially unfamiliar with the PDA quickly learned (within 5 minutes) how to use the decision support system in the trial, and that overall comments about the system were very positive.

The importance of designing a usable interface for the decision support tool, with input from the users, is evident from the above examples. The interface architecture in the UOHI DSS is fairly simple, but it will be of vital importance that it not only leads the NC to the correct advice for the patient, but that it gets them there quickly, easily, and in a way that encourages the NC to use a device they ordinarily would not. With the exception of one of the NCs, the NCs currently do not use PDAs on the job. They are on the phone in real time with the patient, so they will not have time to overcome what might ordinarily be minor inefficiencies in the decision support tool interface. The design principle of consistency will be of particular importance in creating a usable DSS interface. Consistent placement and layout of like items on each screen will ease predictability and visual scanning, and will help make the DSS easy to learn.

Special Tools for Design & Evaluation

Beyond the typical tools in a user centered design process, for instance a storyboard and prototype, pain algorithms and standardized patient profiles were also required for this thesis; the former so the designer could determine the ideal workflow for the DSS, and the latter so participants could interact with simulated patients who would behave consistently.

Pain Algorithms

While currently available algorithms for telemedicine do address many general complaints, these are inadequate when assessing cardiac patients. Slight differences in symptoms can indicate the difference between urgent and non-urgent pain concerns for cardiology and cardiac surgery patients, and with the appropriate assessment a practitioner can and must distinguish between them. Urgent pain would include ischemic pain, which occurs due to tissue or heart damage from insufficient blood flow – for example, when an artery is blocked. Ischemic pain may be indicative of myocardial infarction, or "heart attack." Non-ischemic, non-urgent pain might include the post-surgical discomfort related to a tender – but not infected – incision. Patients can also experience other post-procedural discomfort, of varying levels of urgency.

Because of the subtle yet important differences in cardiac pain, it is important that those developing the associated algorithms have specialized knowledge of cardiac care. The pain algorithms developed for this thesis represent best practices, as determined by a group of experts including NCs, SMEs, a telepractice advanced practice nurse, the Vice-President of Clinical Services and the Quality and Performance Manager from the UOHI, a cardiologist, and a cardiac surgeon.

Standardized Patient Profiles

A standardized patient profile is essentially a simulated patient, in the form of a documented list of characteristics. These standardized profiles are useful in evaluation situations, such as testing medical students, as they allow someone acting in the role of the patient to offer consistent and repeatable responses to questioning. A standardized patient profile includes a name, gender, medical history, and presenting problem. Along with the presenting problem or condition come a number of associated symptoms. For instance, someone with an infected incision might have a fever, swelling around the incision, and thick drainage.

Summary and Hypotheses

In this thesis, cardiac best practice algorithms are introduced via a handheld DSS. Access to these best practices is expected to improve the quality of teletriage performance (Momtahan, 2004), provided a) the best practices are sound, and b) the DSS delivers them in a way that is easily used by NCs while on the phone with a patient. This research encompasses the design and evaluation of the DSS, but does not evaluate the best practice algorithms.

A user centered design process, including hierarchical task analysis, is employed to create a usable system and ensure adequate understanding of the tasks in UOHI teletriage. A new type of diagram, the common level diagram, is developed and discussed in this thesis as a way to help bridge the gap between task analysis and interface design. Usability evaluation for medical DSSs is not well documented in the literature.

It is expected that the procedure used in this thesis will lead to a successful DSS design. Success is defined as improving nurse performance in teletriage, while also being satisfying for the user. As the floor nurse participants are inexperienced in teletriage, it is expected that they will ask more questions than necessary as they probe for patient details without the DSS.

Hypotheses are (1a) that nurses' performance in assessment, and (1b) in recommendations, will improve using the DSS; and (2) that nurses will ask fewer questions with the DSS than without it.

Method

Due to the complexity of this study and the number of people involved at several stages, Figure 2 shows a summary of the tasks undertaken in this study, how they relate to one another, and which participants were involved at each point. Participants and apparatus for each step are described in the procedure that follows.

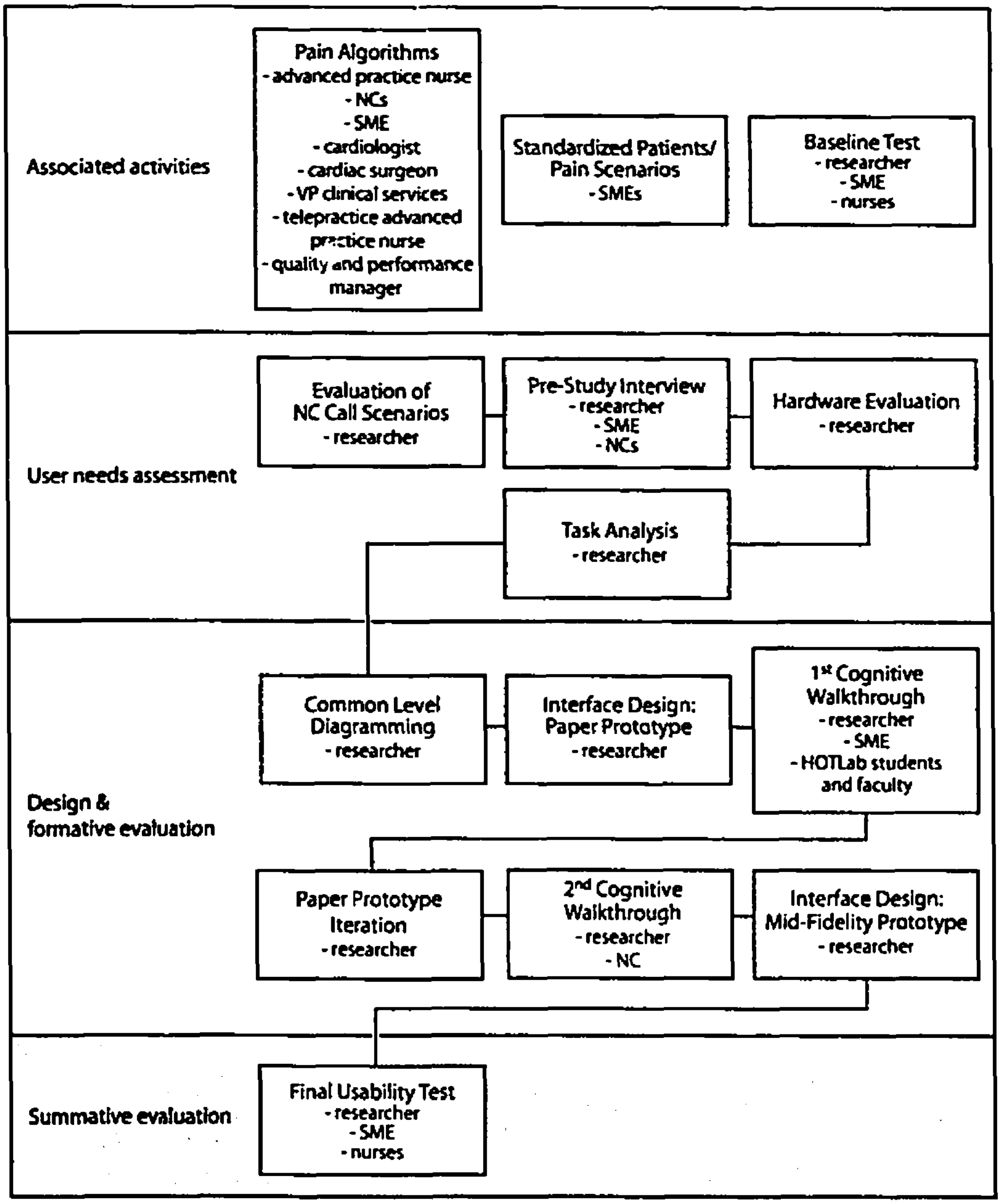


Figure 2: Summary of method and participants

Associated Activities to the Design Process

These tasks were accomplished in parallel to the rest of the researcher's user centered design process. There was therefore some overlap in timeframe between these activities, the user needs assessment, and the prototype development.

Development of Pain Algorithms

Algorithms were developed at the UOHI to capture a standard of best practices for assessing chest pain complaints of cardiology and cardiac surgery patients. The algorithms describe best practices for arriving at appropriate advice, based on the symptoms with which the patient presents. They consist of a series of ordered questions, with following questions contingent on the reply given by the patient. Each branched algorithm describes a finite number of paths, based on different types of pain complaint for cardiology and surgery patients.

Development of these algorithms was accomplished in a focus group, whose purpose was to enable discussion of best practices at an expert level and to achieve buy-in from the NCs as to the algorithm content once finalized. Participating in the group were three NCs, a telepractice advanced practice nurse, the Vice-President of Clinical Services, and the Quality and Performance Manager from the UOHI. The VP of Clinical Services, the Quality and Performance Manager, and the telepractice advanced practice nurse had previous experience developing algorithms. The focus group was organized and run by two SMEs. Call scenario templates (Appendix B) completed by the NCs were used as stimuli for algorithm development.

These algorithms underwent several iterations before they were approved. Final approval of the cardiology algorithm came from the team cardiologist, and approval for the two cardiac surgery algorithms came from the team cardiac surgeon. Though they were approved by expert physicians, time did not permit independent testing of these prior to use in this thesis.

The team generated three algorithms related to chest pain in cardiology and cardiac surgery patients: (1) Cardiology and Cardiac Surgery Chest Pain – ischemic and non-ischemic, (2) Cardiac Surgery – incisional, incision not healing well, and (3) Cardiac Surgery – incisional, incision healing well (Momtahan & Burns, 2005). The pain scenarios chosen for this thesis did not include pain due to incisional problems. In addition to the flowchart algorithms, the so-called "OLDCAR" assessment tool was provided as a source for specific pain characteristics (see Appendix K). "OLDCAR" is an acronym for Onset, Location, Duration, Characteristics, Associated symptoms/Aggravating factors, and Relieving factors. This assessment tool was referenced in the algorithms, and is commonly used in cardiac care to help medical staff probe for details of a patient's pain.

Development of Pain Scenarios and Standardized Patient Profiles

The two SMEs developed four pain scenarios. There was one scenario for each of the following types of pain complaint: non-urgent cardiac surgery, urgent cardiac surgery, non-urgent cardiology, and urgent cardiology. The following specific ailments were chosen as common examples of each type of pain (see Table 2). The two cardiology scenarios followed algorithm (1) above. The cardiac surgery scenarios followed algorithm (3).

Scenario	Cardiac care area	Urgent or non-urgent
1: Post Pericardial Syndrome (PPS)	Cardiac surgery	Non-urgent
2: Ischemic pain	Cardiology	Urgent
3: Cardiac tamponade	Cardiac surgery	Urgent
4: Stent pain	Cardiology	Non-urgent

Table 2: Pain Scenarios

Each pain scenario was developed from a standardized patient profile, whose characteristics matched the algorithm for the pain complaint in question. These "patients" were created by two SMEs, based on the algorithms and their practical experience.

Baseline Test

Because some of the NCs participated in development of the algorithms and they are very limited in numbers at the UOHI, the NCs were not used as participants in DSS prototype testing. Instead, participants in the baseline and DSS tests were cardiac care nurses from the UOHI who work with hospitalized cardiac patients. Recruitment took place at the UOHI via poster solicitation (Appendix P). Because response to the posters was very limited, nurses were also recruited by word of mouth, through one of the SMEs.

They were offered the flexibility to participate either on shift, or on a day off. They were compensated with a parking pass at the end of each session.

12 nurses completed the baseline testing. Seven of these also completed the DSS test. Their experience ranged from 1 to 25 years in cardiac nursing, and from 5 to 30 years in general nursing. Of the seven who completed the whole study, four (P1, 2, 5, and 7) had some experience managing patient calls and three (P3, 4, and 6) did not. An SME acted in the role of the bunker (the UOHI attendant who transfers incoming patient calls to the NCs) and the patient during the baseline and DSS tests. This experiment did not use any real patients as participants.

Apparatus for the baseline test included a telephone handset, paper and pen. Also present in the room were a Polycom speaker phone, video recording equipment, desk, and two chairs.

This baseline provided initial data for the number of questions asked by each participant in each scenario, and for performance scores on quality of assessment, quality of recommendations, and correctness of conclusion. "Quality of assessment" measured nurses' ability to ask the right questions in assessing the patient's condition. "Quality of recommendations" measured their ability to give the patient correct advice based on the presenting problem in each scenario. "Correctness of conclusion" measured whether or not the nurse correctly guessed what was wrong with each patient.

Each of the 12 recruited nurses participated in individual sessions that generally lasted less than one hour. During these sessions, participants filled out a pre-interview questionnaire (Appendix R). They then completed the four pain scenarios with the "patient" on the phone, using only a pen, paper, and their own knowledge. These are the tools that would normally be available to nurses. Though nurses would normally see a patient in person and have access to their chart on the ward, this would not be the case upon taking a phone call. Baseline sessions were scheduled approximately six weeks prior to the DSS test.

Experiment Preparation

The researcher sat across the table and slightly away from the participant, such that she did not distract her during the test. The telephone handset, pen, and paper were positioned within easy reach of the participant. The speaker phone rested between the participant and the researcher, and video recording equipment was placed behind the speaker phone to capture audio. For the baseline test, the lens cap remained in place during recording as video output for this session was not required. See Figure 3 for experiment setup.

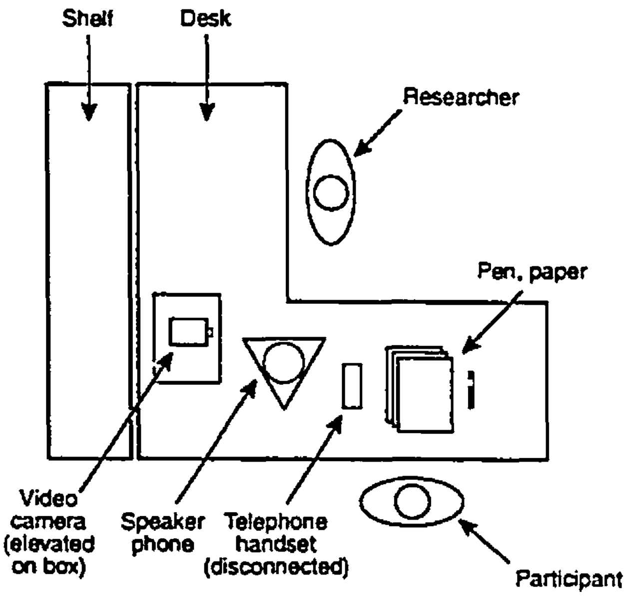


Figure 3: Baseline test setup

Pain Scenarios

The presentation of the four pain scenarios was randomized to avoid serial order effects. In all scenarios, the SME in the role of the patient made an effort to answer the nurse's questions in an appropriate way, neither volunteering more information than requested, nor being furtive and vague. For each pain scenario, the SME referred to the corresponding standardized patient profile during the call to ensure she was giving consistent answers. Each standardized patient profile listed, in logical order determined by the algorithm, questions that the NC would likely ask with corresponding answers for that scenario. The profiles also contained answers to questions not necessarily in the optimal flow of questioning. Throughout the baseline and DSS tests, if a participant asked a question that was not on the list, the SME gave an answer consistent with the cause of pain in that scenario. She then added the new question and answer to the list, ensuring that a consistent response would be given should the same question be asked by another participant.

To preserve the SME's anonymity and increase semblance to a real telephone call, the SME was in another room and communicated via telephone throughout the test.

The researcher read an introductory script before the pain scenarios began, telling the nurse that they would be acting in the role of an NC, and that we wanted them to assess the patient's condition and advise them accordingly (Appendix S). To more closely mimic real-life use, nurses were asked to hold the telephone handset to their ear during the call even though the speaker phone was in use to record the session.

To begin each scenario, the researcher called the "bunker," who was an SME acting in the role of the nurses' switchboard operator, to indicate we were ready to start. The bunker called back, and the participant picked up the phone handset. The bunker gave the patient's name, and the name of their Heart Institute physician. The bunker then connected the participant with the patient (note that the voice of the bunker and the patients were the same). Participants proceeded through the phone call using a pen and paper to record whatever they wished. The participant marked the end of the call by hanging up the telephone handset.

User Needs Assessment

To address the issue of optimizing the decision support tool as a whole for the UOHI teletriage environment, qualitative data was gathered in the preliminary stages to learn about how NCs currently handle patient calls and to learn about the constraints and features of the Tungsten T3 PDA unit. These steps are described in more detail below. The final product of this phase was a requirements and constraints document (Appendix F).

Learning About How NCs Handle Patient Calls

The eight nursing coordinators (NCs) employed by the UOHI range in experience from six to 32 years as a cardiac nurse, and from three to 23 years as an NC at the UOHI. Only one of the eight NCs had prior experience with Personal Digital Assistants (PDAs).

The eight NCs were individually interviewed about existing teletriage procedures to identify problems or weaknesses, and to learn any common language or abbreviations used by NCs when processing patient phone calls. The interview questions (Appendix C) were created in consultation with the SMEs for preliminary data gathering, and were administered by the SMEs. The NCs had the option of returning the questionnaire in person or via email. The results of the NC interviews are summarized in the Interview Responses document (Appendix D).

The current layout and content of the Telepractice Documentation Record (Appendix A) was observed. This is the paper form currently used by the NCs to document patient calls. Current working environment and additional duties of the NCs were discussed with the SMEs.

Current task workflow, documented informally in the form of call scenario templates (see Appendix B) by the NCs, also informed the task analysis. This informal documentation is likely to yield good information about the true way NCs perform their job, even in the absence of published manuals. Call scenarios completed by the eight NCs (see Appendix B for an example) were used to help determine how patient calls typically proceed. Though the prototype design focused on pain complaints, for reason of scope all types of scenarios were reviewed to assess the general nature of typical incoming calls. A common level diagram was created to map these call scenarios, and determine where similarities lie in content and structure. This diagram is presented in the Discussion.

Evaluation of Hardware Features and Constraints

A working Palm Tungsten T3 unit was evaluated by the researcher to determine constraints and features of the display, basic functionality, and hardware that could affect the design of the call aid interface. The QuickStart tour was completed, and preferences and options available to the end user were explored. In particular, font size and common existing interface widgets were investigated, to determine common use of screen space. Accompanying documentation was also read.

During informal input from the NCs to the SME, they suggested they may be more comfortable with a keyboard for data entry. Testing the T3 unit with a hard keyboard interface lay outside the scope of this thesis, however the literature suggests that point and click interaction tends to be more successful for data entry in a handheld computing context.

Task Analysis

The larger task analyzed in the design of the DSS was "field a patient phone call," specifically in relation to a pain concern. This research focused on cardiac surgery and cardiology pain, and particularly around the choices surrounding four pain scenarios chosen by SMEs. Pain algorithms (Appendix J) were used as input for an HTA. The data gathered during SME consultations and NC interviews also provided material for the HTA. This data supplemented the algorithms, informing the holistic flow of the system from call initiation to termination.

The final HTA diagram shows the task flow for patient calls, reflecting a generalized call structure in response to a pain concern. This diagram establishes an optimized flow of questions in conversations between NC and patient, and determines a logical information architecture for the prototype.

Design & Formative Evaluation

Common Level Diagram

A common level diagram was generated to reflect each pain scenario, based on the pain algorithms, the HTA diagram, and the context analysis. This diagram is presented in the Discussion. Finer-level data from the context analysis that may not have been reflected directly in the HTA could, at this stage, help determine how to address common aspects of the call – for example, getting the patient's name and other required information.

Ideation and Selection

This phase of the design process focused on concept exploration, and on generating as many ideas as possible without being hampered or slowed by a tool to render them. Materials used for sketching included a pencil, paper, and a template indicating the physical screen proportions of the T3 (see Figure 4) to ideate concepts for the interface. This template was created slightly larger than actual size to facilitate sketching and evaluation.

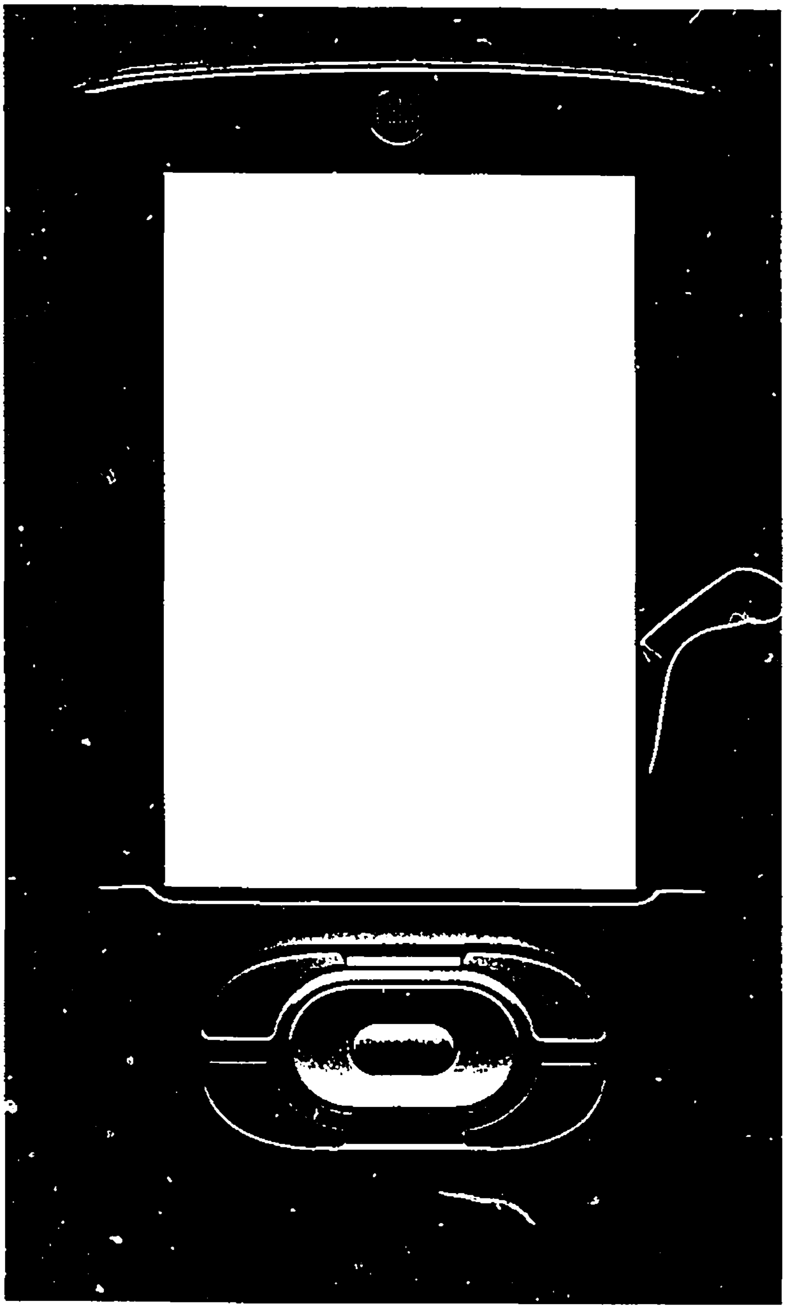


Figure 4: Sketch template

Sketches were compared against the requirements generated by the preliminary data gathering, and against the pain algorithms. Strong ideas were selected, synthesized, and developed by the designer into a logical solution from which to form the storyboard.

Generation of a Storyboard and Paper Prototype

The storyboard began with a workflow chart (Appendix H) of a single pain scenario (Post Pericardiotomy Syndrome). Figure 5 below shows how the workflow chart was laid out.

Step	Text	Options	Additional information
1. Primary complaint	Primary complaint:	Check box list: - ***Chest pain (go to 2)*** - Shortness of breath - Weakness - Question about meds - Generally unwell (go to 2)	If user checks "Generally unwell" and neither "chest pain" nor "SOB" are selected, pop up following message: "Probe for chest pain and shortness of breath before proceeding. [OK]" "Next" button appears once an item has been checked.

Figure 5: Workflow Chart Sample

An associated paper prototype was developed by hand using hard copies of the T3 sketch template, with one page per screen. Smaller pieces of paper contained lists and menu items associated with each screen. This prototype showed low-fidelity interface components, as well as interaction strategies (see Figure 6 for example).

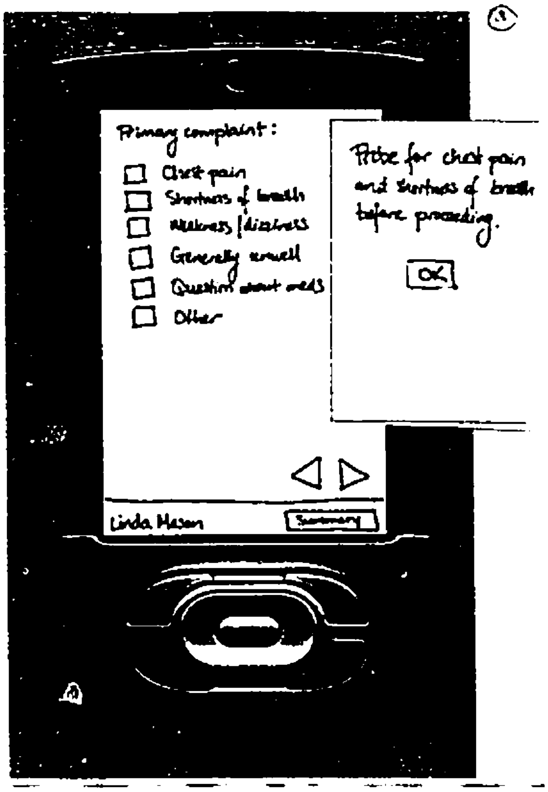


Figure 6: Paper Prototype Screen, 1st Iteration

Cognitive Walkthrough

Participants in the first cognitive walkthrough of the paper prototype included five students and three faculty from the Carleton University Human Oriented Technology Lab (HOTLab), as well as one of the SMEs, the thesis researcher, and a student observer associated with the UOHI DSS project.

The cognitive walkthrough took place around a large table in the HOTLab boardroom, and took about one hour. There were ten active participants in the walkthrough, including the researcher and one of the SMEs, and one observer who did not actively participate. Each participant received a copy of (1) the HTA diagram (Appendix G), (2) the requirements summary (Appendix F), and (3) the workflow chart (Appendix H). A copy of the common level diagram showing all four pain scenarios was also available for perusal.

At the start of the session, participants received a brief introduction to the project. The researcher informed participants of the goals of the handheld decision support tool, as well as the short-term interface focus (pain complaints). A list of things to think about was also read aloud, for those unfamiliar with the purpose and procedure of a cognitive walkthrough (Abowd, 1995; see Appendix I). The paper prototype screens were alternately held up and passed around so that participants could comment on the actions in each screen. The participants talked through the interface one screen at a time, verifying that all steps were present and clear. As problems were found, the researcher recorded them.

Iteration

The paper prototype was iterated based on the comments generated in the cognitive walkthrough. This second prototype was presented to the two SMEs for feedback, and a second cognitive walkthrough was performed with an NC before development began on the mid-fidelity prototype.

The paper prototype contained the optimal path for one scenario (Post Pericardiotomy Syndrome). Following the cognitive walkthrough and subsequent iteration, it served as a template for interaction for the other three scenarios.

Development of Mid-Fidelity Prototype

Mid-fidelity electronic prototyping was chosen over paper prototyping for the DSS test to improve ecological validity. Adobe Photoshop and Macromedia Dreamweaver UltraDev were used to produce four mid-fidelity prototypes, one for each pain scenario. The prototypes contained sufficient interface functionality and content to allow the participants to navigate through the four pain scenarios. The prototype was developed taking into account the end form-factor of the T3 PDA, and bearing in mind that it would be tested on a Tablet PC using a stylus as an input device. Coding for the prototype was done in html and dhtml.

Summative Evaluation

DSS Test

Seven of the original 12 participants completed the DSS test. Of the other five, one participant left her job at the Heart Institute, one moved out of the country, another was out of the country for an extended period, one was on a long vacation, and the other was simply unavailable during the DSS testing period. The same SME who participated in the baseline test acted again in the roles of the bunker and patients for the DSS test. The SME did not personally evaluate the interface during the DSS test.

Apparatus was similar to the baseline test with the addition of an LCD projector, a Palm Tungsten T3 PDA including stylus, and a Toshiba Portégé M200 tablet PC, with 1MB level 2 cache and 32MB Video RAM, running Microsoft Windows XP on an Intel

Centrino 1.6GHz processor. The T3 was presented with only the software that comes installed from the manufacturer. The participants did not have access to a pen and paper for the DSS test, except Participant 2 who was the first participant in this trial. All interaction with the tablet occurred through the included stylus.

Each DSS test session, including preliminary interaction exercise and evaluation of the T3 hardware, took slightly more than one hour. Evaluators were volunteering their time, but were compensated for parking.

Experiment Preparation

The researcher sat across the table and slightly away from the evaluator, such that she did not distract her during the test. The projector cast an image of the Tablet PC screen onto the side wall. Direct recording of the participant's interaction with the Tablet was not desirable, as it would have required perching the camera obtrusively over the participant's shoulder. Additionally, a projected image on the wall showing the Tablet screen allowed the researcher to see what the participant was doing without hovering over top of the Tablet and distracting them. The video camera recorded this projected image, showing the screen and mouse movements. The video camera also captured audio during the experiment. The camera was not directed toward the participant's face. The recording component of the test was optional, and the participant's decision to opt in or out was stated on their informed consent form. None of the participants refused to be recorded.

Before handing the Tablet PC to the participant for the Interaction Exercise, the researcher read the script in Appendix T, section a. The researcher positioned the Tablet PC flat on the table, with the exercise launched, and handed the stylus to the participant.

Before the Pain Scenarios portion of the test, the researcher read the script in Appendix S, section b. She launched the prototype so that the first screen was visible on the Tablet, and positioned the Tablet again in front of the participant. The telephone handset was positioned near the participant's non-dominant hand, and the stylus rested near their dominant hand. See Figure 7 below for experiment setup.

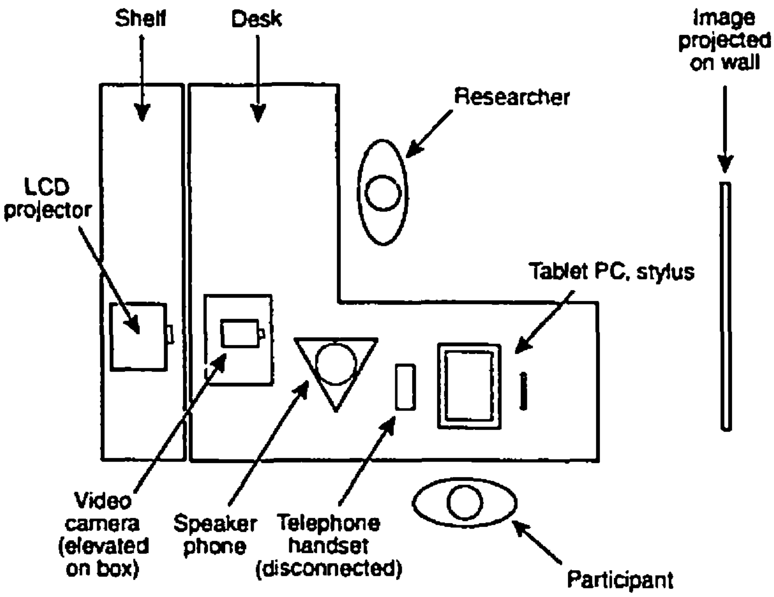


Figure 7: DSS Test Setup

Tablet PC Interaction Exercise

Each evaluator participated in the short interaction exercise that comes built in to the Tablet PC. This exercise was not recorded or measured, and served only to give each evaluator equal opportunity to practice interacting with the Tablet PC via the stylus prior to the test. All participants were first-time users of the Tablet PC.

Practice Scenario

Following the first participant in the DSS test (Participant 2), it became apparent that the rest of the participants would likely benefit from some practice on the system before being asked to use and evaluate it in a simulated working environment. Therefore all participants except Participant 2 received the following practice scenario. The researcher first walked the participant through a sample scenario, which was based on a fictitious patient with a chest cold rather than a cardiac pain concern. Following this, the researcher played the role of that same patient, and allowed the nurse participant to click through the tool on their own while asking questions of the patient. This gave them extra practice with the stylus, using the interface components in the prototype. The facilitator pointed out the omnipresent "Quick Summary" button, which allows the user to see a summary of all information gathered to that point during a call.

Pain Scenarios

The pain scenarios proceeded exactly as in the baseline test, but the participants used the prototype DSS to assist in assessing the patient. Scenario order was randomized, and participants received them in a different order than in the first session to avoid order effects. Patient and physician names were changed from the baseline test.

The first participant in the DSS test had access to a pen and paper, and alternated between using the prototype DSS and the paper. Following this session, it was decided not to allow other participants access to pen and paper during the test, to encourage use of the DSS on the tablet without distraction.

The first participant also experienced some difficulty using the keyboard functionality in the prototype. To minimize any frustration that could arise from entering text information, since the on-screen keyboard was only partially functional and the tablet software keyboard kept popping up on the screen, the researcher entered the patient and physician names as well as recording "Other" fields for all participants after the first one.

Upon call initiation as per the baseline test, the participant proceeded through each phone call using the prototype for guidance. During the call, the researcher used a log sheet (Appendix U), to track comments made by the evaluator, observations about the interaction, whether there was a need for researcher intervention to continue at any point, and whether they arrived at the correct end point in the algorithm. When the participant arrived at the point where the decision support tool would prompt them with an automatically-generated assessment, the researcher interrupted the call, prompted the evaluator to look at the Call Summary, and asked them to make an assessment of the patient's problem. The researcher then instructed the participant to advise the patient accordingly and end the call. Following the call, the researcher asked the evaluator to click "Next", and mentioned that they would see an automatically-generated assessment prompt that may or may not be appropriate given the scenario. The researcher then asked the participant if they agreed or disagreed with the automated assessment.

Following each scenario, the participant was asked to fill out a post-scenario feedback form (Appendix V). This measured the participant's reported comfort level.

Participants were asked to mark a line on a continuous line scale that indicated their comfort level with the system after each scenario. The midline mark was identified as neutral. Score was indicated by a measurement on this 10cm line. A measurement/score of 5.0 was the midline neutral point. The goal was to determine whether nurses' comfort with the DSS would increase as they used it.

After completion of all the scenarios, the evaluator completed a post-test questionnaire (Appendix W) to measure satisfaction. The questions in this questionnaire were derived from the IBM Post-Study Usability Questionnaire (Lewis, 1995). The same line scale was used for satisfaction as for comfort.

Evaluation of T3 Hardware

Following the prototype test, the facilitator moved the Tablet PC aside. She read the script from Appendix T, section c. She showed the evaluator how to turn on the T3, slide the display open, remove the stylus, and use the hard button on the side of the unit to start and stop a voice recording. She then handed the unit to the evaluator in the closed position, with the stylus in situ, and asked the evaluator to try it out, while they had the telephone handset in their other hand. There were no restricted areas on the PDA, and evaluators were able to explore any of the built-in functionality they chose. The evaluators were instructed to think aloud as they were using the device, noting any desirable characteristics or problems as they went. The facilitator took notes recording these thoughts.

The first participant to run in the second session was enthralled with the T3 and spent 35 minutes playing with it. Because the participants were often on shift and in the interest of time, the instructions for this section were subsequently changed to limit each evaluator to 5 minutes with the T3.

Experiment Termination

At the completion of T3 hardware evaluation, the facilitator informed the evaluator that they were done. The evaluator was then presented with the debriefing form (Appendix X), and given the opportunity to ask any questions. They were thanked for their time, given a parking pass, and asked not to discuss the test with the other nurses.

Results

This section begins with a description of how the data were scored. Nurse performance is analyzed next, comparing baseline results to those obtained with the DSS. Performance is measured in terms of assessment quality, recommendation quality, and correctness of conclusion. Performance is then analyzed against agreement with the DSS' automated assessment, and also against reported confidence. Additionally, post-scenario comfort and post-test satisfaction with the tool are reported. Screens in the DSS where participants deviated from the algorithms are described. Lastly, participants' comments on the T3 hardware are summarized. Since not all participants took part in both the baseline and usability tests, data are reported only for those who completed both tests. Nonparametric statistics were applied throughout, due to the small number of participants.

Data Scoring

The scoring system was devised by two SMEs, as a separate activity in parallel to participant testing. Using the algorithms and their own clinical expertise, these SMEs determined a list of questions that they considered essential or beneficial to a good assessment for each pain scenario, as well as essential or beneficial recommendations. Assessment points were grouped separately from recommendation points. Essential assessment questions and recommendations were assigned 2 points each, and beneficial questions and recommendations were assigned 1 point each. The two SMEs scored transcripts of the audio recordings independently, to minimize bias. In determining where participants strayed from the screens in the interface so as to identify mismatches between the SMEs' and the users' models of questioning, a SME also used a copy of the mid-fidelity prototype.

The SMEs' scores for each participant in each scenario were totaled, so that each participant received one score for assessment and one score for recommendations. If one SME gave a total of 4 out of 6, and the other gave 5 out of 6, the participant's total score would be 9 out of 12. These scores are expressed in the results as a percentage of the possible total, since each scenario had a different number of possible points.

These lists of essential/beneficial questions and recommendations were iterated after the second session (the usability test on the DSS), and the baseline scores were recalculated against these new totals. Iteration was deemed necessary by the SMEs after seeing the transcripts of the usability test, as the cardiac nurses had asked some beneficial questions that the SMEs had not thought of initially. Inter-rater reliability scores for each scenario in the baseline and DSS test are shown in Table 3.

	Kappa:	PPS	Ischemic Pain	Cardiac Tamponade	Stent Pain
Baseline	Range	0.81 - 1	0.47 - 1	0.74 - 1	0.71 - 1
	Average	0.96	0.93	0.97	0.95
DSS Test	Range	0.67 - 1	0.72 - 1	0.72 - 1	0.44 – 1
	Average	0.95	0.97	0.98	0.94

Table 3: Inter-rater reliability

Nurse Performance

Nurse performance was measured in three ways for each scenario: (1) quality of assessment, (2) quality of recommendations, and (3) correctness of conclusion. Quality of assessment and quality of recommendations were scored as described above, and are reported as a percentage of the possible score for that scenario. Correctness of conclusion was scored either "yes" if both SMEs agreed that the conclusion was correct, "no" if both agreed it was incorrect, or "undetermined" if the SMEs disagreed.

Additionally, (4) participants' confidence in their recommendations and conclusion was assessed to determine if they felt more confident with or without the DSS. This was compared to actual performance. Finally, (5) participants' agreement with the automated DSS conclusion was assessed.

(1) quality of assessment

Hypothesis (1a) stating that nurses' quality of assessment would improve with the DSS, was tested by comparing assessment scores from the baseline (initial) test to those from the DSS (final) test as described above.

Figure 8, showing the quality of assessment score for each participant collapsed across all four scenarios, suggests that the scores were higher with than without the DSS for all participants. Results by participant were not statistically analyzed, because there were only four scenarios.

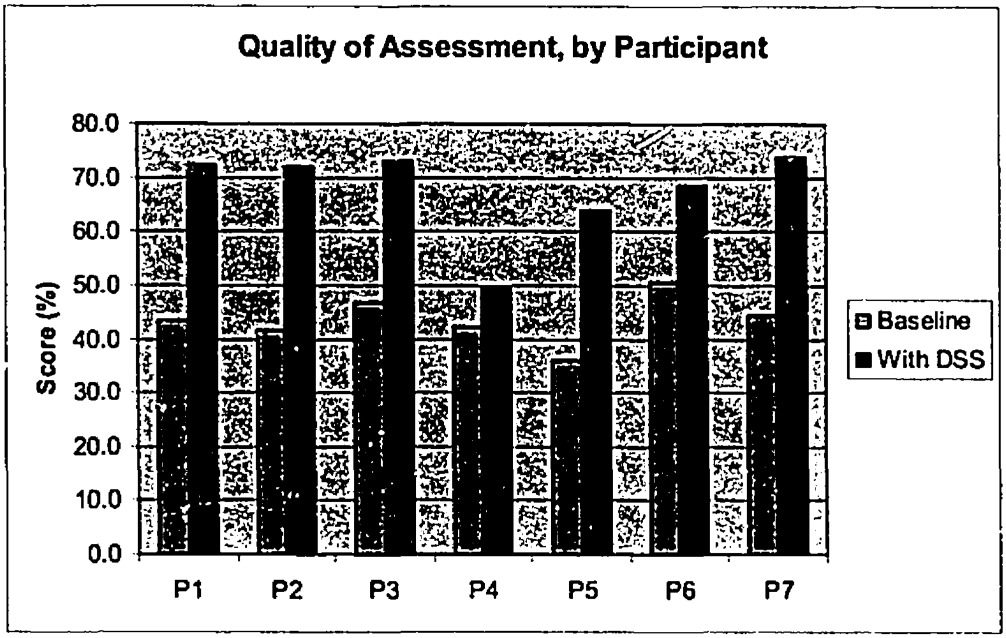


Figure 8: Quality of Assessment, by participant

In order to ascertain if assessment performance improved in each of the four scenarios, Figure 9 shows the quality of assessment scores for each scenario. While this figure suggests that performance scores improved substantially from the baseline to using the DSS in the case of Stent Pain and Post Pericardiotomy Syndrome (PPS) – the non-urgent scenarios, this improvement was less evident in the case of Ischemic Pain and Cardiac Tamponade – the urgent scenarios. The Wilcoxon Signed Ranks Test in Table 4 indicates that, statistically, quality of assessment did improve for every scenario with the DSS.

These results support the assumption from hypothesis (1a) that that nurses' performance in assessment would improve using the DSS.

	Z	p
PPS	-2.366	.018
Ischemic Pain	-2.371	.018
Cardiac Tamponade	-2.366	.028
Stent Pain	-2.201	.028

Table 4: Wilcoxon Signed Ranks Test, Assessment Quality

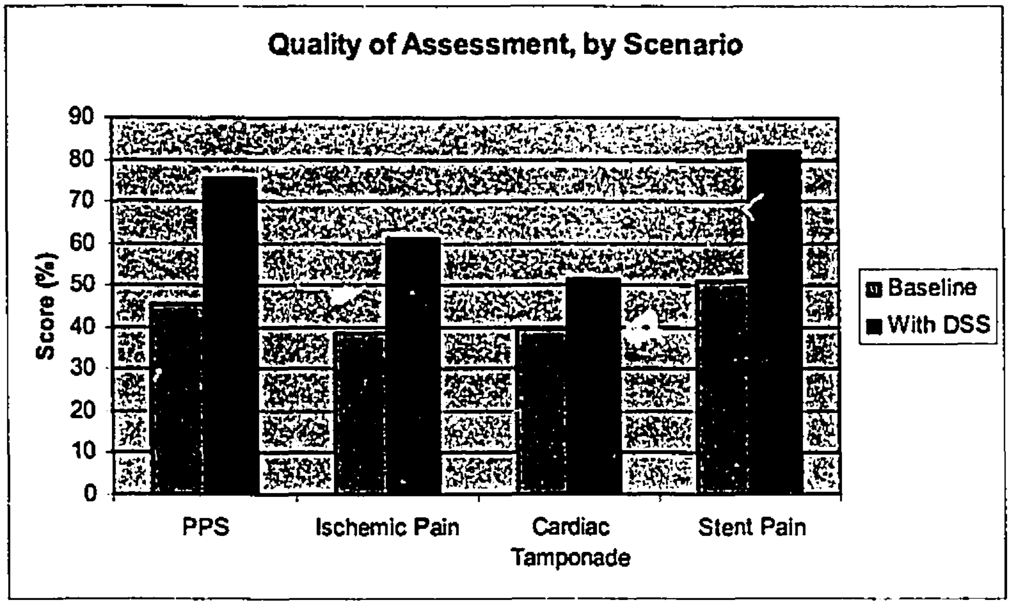


Figure 9: Quality of Assessment, by scenario

(2) quality of recommendation

Hypothesis (1b) stated that nurses' recommendation performance would improve with the DSS. Figure 10 suggests that this was true only for three of the seven participants (participants 1, 2, and 4). Recommendation scores for the remaining four participants (5, 7, 8, and 10) did not appear to improve with the DSS.

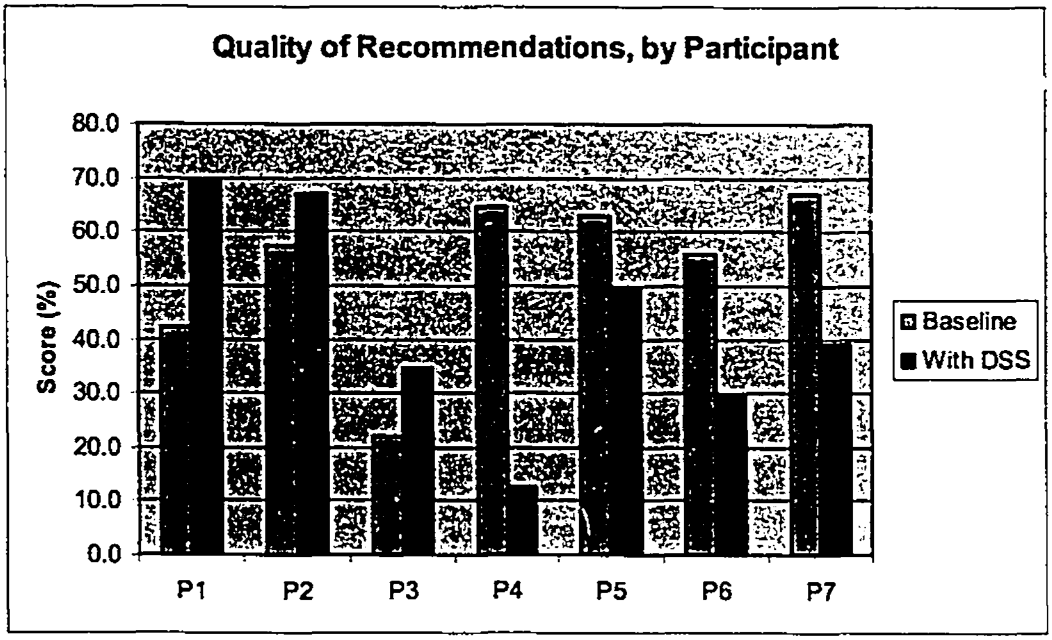


Figure 10: Quality of Recommendations, by participant

As before, these data were then plotted for each scenario and collapsed across participants as shown in Figure 11. The figure suggests that recommendation performance declined at least slightly across all scenarios. This decline was most evident in the Cardiac Tamponade (urgent) and Post Pericardiotomy Syndrome (PPS) (non-urgent) scenarios. However, a Wilcoxon Signed Ranks Test (Table 5) revealed no significant effect ($p > 0.05$). Hypothesis (1b) was therefore not supported.

	Z	p
PPS	-1.604	.109
Ischemic Pain	-.272	.785
Cardiac Tamponade	-.756	.450
Stent Pain	-.271	.786

Table 5: Wilcoxon Signed Ranks Test, Recommendation Quality

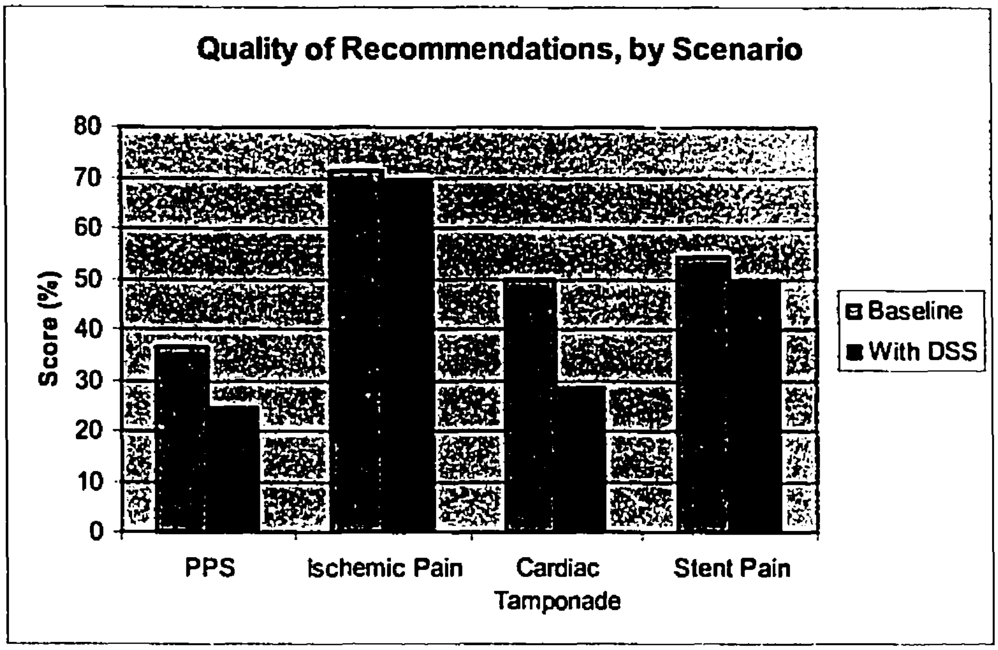


Figure 11: Quality of Recommendations, by scenario

(3) Correctness of conclusion

In the baseline test, if the participants did not volunteer their impression of what the patient's problem was during the call, the researcher asked them afterward what they thought the presenting condition was. This response was compared against the correct conclusion for each scenario (for example, in the ischemic pain scenario, a correct conclusion would be "ischemic pain," "heart attack," or similar). In the final test with the

DSS, the SMEs determined from the transcripts whether or not they thought the participant had the right condition in mind based on their comments during the test.

After participants had assessed the patient's condition and recommended an action during the final test, the DSS provided a possible conclusion and recommendation based on the patient's symptoms, and the participant was asked to agree, disagree, or declare their uncertainty with respect to the DSS's recommendation. Figure 12 shows the level of agreement for each of the four scenarios. For scenarios 2 (urgent ischemic pain) and 4 (non-urgent stent pain), all participants agreed with the DSS. For Scenario 1 (PPS), three participants disagreed with the DSS and one was unsure. Of those, two participants claimed they had never heard of PPS and that they therefore could not assume the given auto-assessment was correct. For Scenario 3, one participant disagreed with the auto-assessment and two were unsure. The one who disagreed said that she would take such a message into account, but that the particular assessment was not the first that came to mind. One of the unsure participants said that the assessment might be correct, and she wouldn't rule it out. The other doubted the assessment because the patient "did not sound like she was in distress."

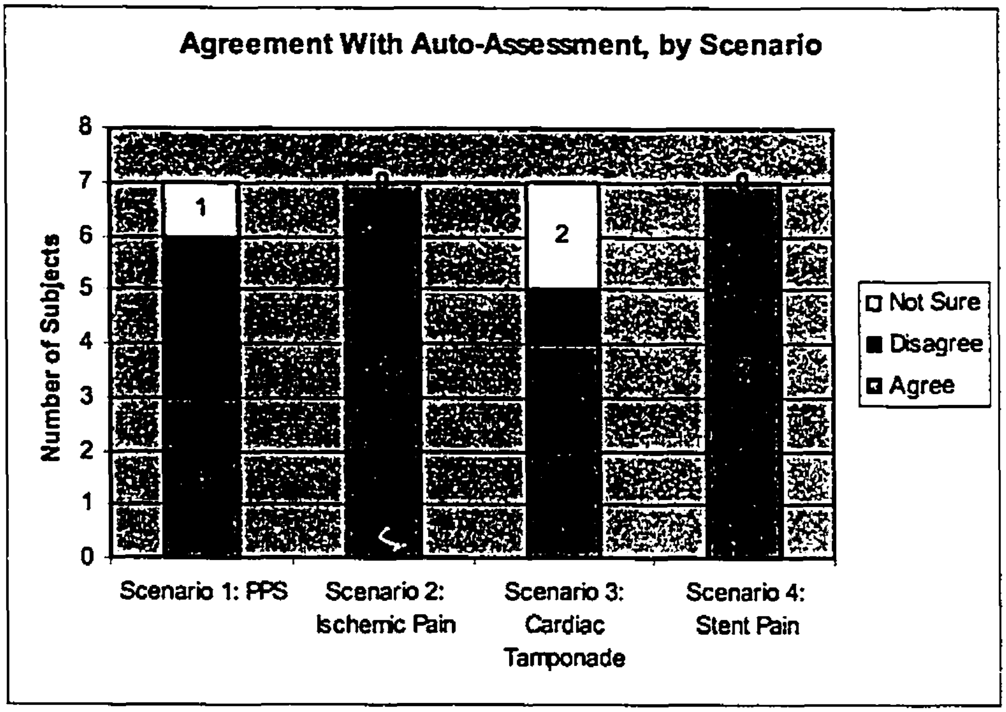


Figure 12: Agreement With Auto-Assessment, by scenario

It is interesting to note that the two scenarios in which participants all agreed with the DSS, Ischemic Pain and Stent Pain, were those for which they scored best on their own recommendations. The PPS scenario yielded the lowest quality of recommendation scores and also the lowest level of agreement among the nurses. Thus, the two sets of scores complement each other. This suggests that even if the nurses had seen the DSS assessment before giving their own advice, they still may not have improved their performance in that area.

However, inspection of the correct conclusions related to agreement with the DSS presented in Table 6 shows that there are instances where nurse performance could improve in real-life usage of the tool. Gray boxes in the table show where the participant was incorrect in their own conclusion and scored less than perfect on their recommendations, but agreed with the DSS auto-assessment. These indicate instances where improvements could occur in real-life usage, since the nurses would have access to the automated assessment as part of normal DSS use. With the tool, these nurses would likely have made better recommendations.

		P1	P2	P3	P4	P5	P6	P70
PPS	*Correct conclusion*	No	No	No	No	Yes	No	Yes
	Agree with DSS	Not sure	No	No	No	Yes	Yes	Yes
	Score, quality of recommendations	22.2	22.2	22.2	0	22.2	22.2	22.2
Ischemic Pain	*Correct conclusion*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Agree with DSS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Score, quality of recommendations	50	100	50	50	100	50	87.5
Cardiac Tamponade	*Correct conclusion*	No	No	No	No	No	No	No
	Agree with DSS	Not sure	Yes	Yes	Yes	Not sure	No	Yes
	Score, quality of recommendations	100	100	0	0	0	0	0
Stent Pain	*Correct conclusion*	No	Yes	No	No	No	Yes	Yes
	Agree with DSS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Score, quality of recommendations	100	40	60	0	50	20	40

Table 6: Instances where performance might improve in real-life usage, based on correctness of conclusion vs. agreement with DSS

(4) Participants' confidence ratings

In the post-test questionnaire following the usability test, participants rated their confidence in (1) their quality of recommendations, and (2) correctness of their conclusion (Appendix W, Questions 13, 14) generally across all scenarios. There were three checkbox options, to indicate they were either "more," "equally," or "less" confident with the DSS compared to without it.

Figure 13 shows participants divided into those who were equally confident (four) in their recommendation quality with or without the DSS, and those who were more confident (three) in their recommendation quality when they had the DSS. Of the four participants who were equally confident in their recommendations with and without the DSS, two improved their score with the DSS (P2 and 3) while two declined (P4 and 5). Of the three who reported being more confident in their recommendations with the DSS, only one improved (P1); two declined (P5 and 6). No participants reported being less confident in their recommendations with the DSS, suggesting that participants did not feel hindered by the DSS in giving advice to the patient. Of those who were more confident, one participant commented she liked the system giving them "possible diagnosis [from] patient's complaints".

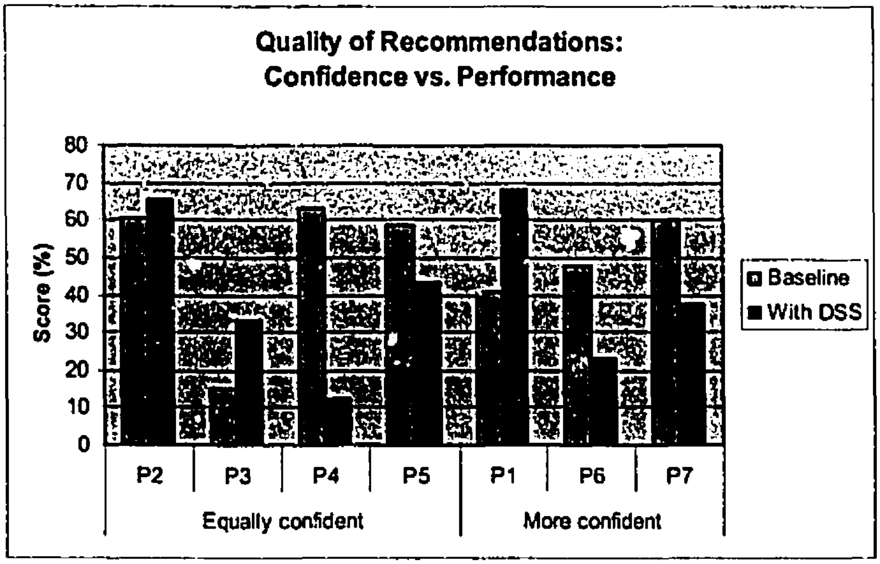


Figure 13: Quality of Recommendations: Confidence vs. Performance

Figure 14 shows the number of scenarios for which participants guessed the correct conclusion in the baseline (without DSS) and final (with DSS) tests, and compares this with their reported confidence levels. Interestingly, one participant who claimed she was less confident in her conclusion with the DSS actually got more conclusions correct with the DSS across the four scenarios. Of the three who reported equal confidence with and without the tool, two did better with the DSS and one stayed the same. Of the two who were more confident with the tool than without it, one stayed the same and one showed a decline in number of correct conclusions. Note that "conclusion" read as "assessment" on the questionnaire. According to the SMEs and based on comments received from participants for this question, it was interpreted by the nurses to mean "conclusion."

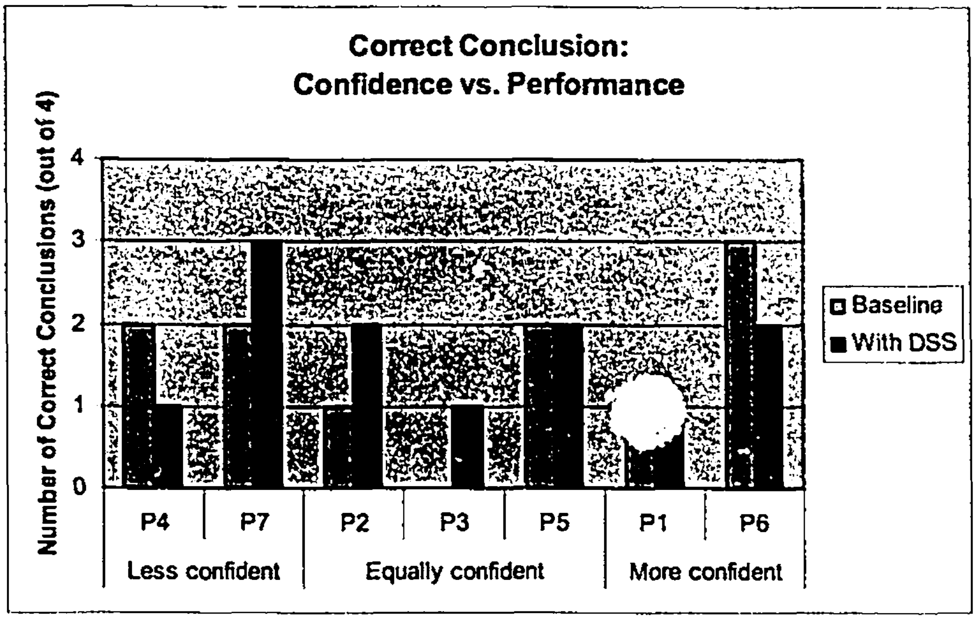


Figure 14: Correct Conclusion: Confidence vs. Performance

One participant who reported she was more confident with the tool said it "gave a better picture of the patient's complaints" and that she knew she was asking appropriate questions to get her information. Of those who were less confident, one attributed her reduced confidence to her inexperience with the system. The other forgot about the availability of the "Quick Summary" button, and believed she had to remember all the patient's answers until she got to the end of the call. From these results, there appears to be no discernable relationship between confidence and performance.

Efficiency of Question-Asking

In addition to scoring essential and beneficial questions in each transcript for every scenario, one SME scored "questions asked" by counting the total number of questions asked, and classifying them as "on" or "not on" the list of essential/beneficial questions. Figure 15 shows the average number of questions asked by nurses during assessment for each scenario. This figure suggests that participants asked more questions with the DSS than without it.

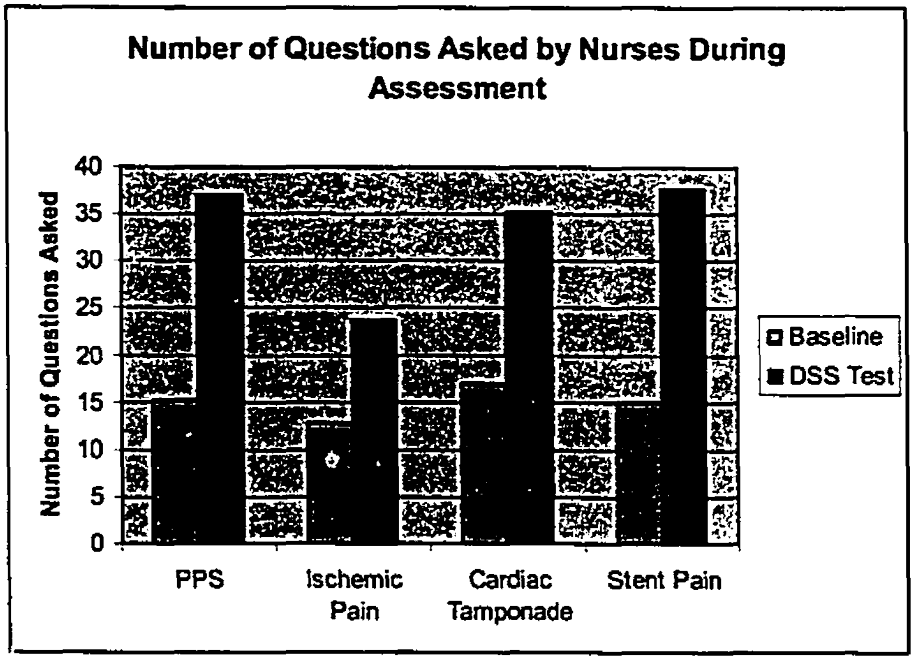


Figure 15: Average number of questions asked by nurses during assessment

Hypothesis (2) stated that nurses will ask fewer questions with the DSS than without it. A Wilcoxon Signed Ranks Test (Table 7), comparing the number of questions asked in the baseline test and the DSS test, indicates that participants in fact asked significantly more questions with the DSS than without it ($Z= -2.31$, $p<0.05$) These results refute Hypothesis 2.

	With DSS – Baseline
Z	-2.371(a)
Asymp. Sig. (2-tailed)	.018

Table 7: Wilcoxon Signed Ranks Test for total number of questions asked

However, in addition to comparing the number of questions asked, the efficiency of questioning was also assessed. Efficiency was measured as a proportion of questions asked that were on the SME's list of essential and beneficial questions. These lists were agreed upon by two SMEs, and were iterated following the final test, before scoring was done. This iteration was deemed necessary because the nurses asked beneficial questions during the test that were not on the original lists. The SME's lists of questions were not tested prior to using them for coding. Questions outside of these lists are purposely not called "bad" or extraneous questions, as it is possible that further iteration to the lists could be beneficial.

Figure 16 shows the proportion of assessment questions asked that were on the list compared to not on the list. It suggests that most of the additional questions asked with the DSS were marked in the SMEs' list. Furthermore, the number of questions not on the list remained fairly constant across scenarios between the baseline and DSS

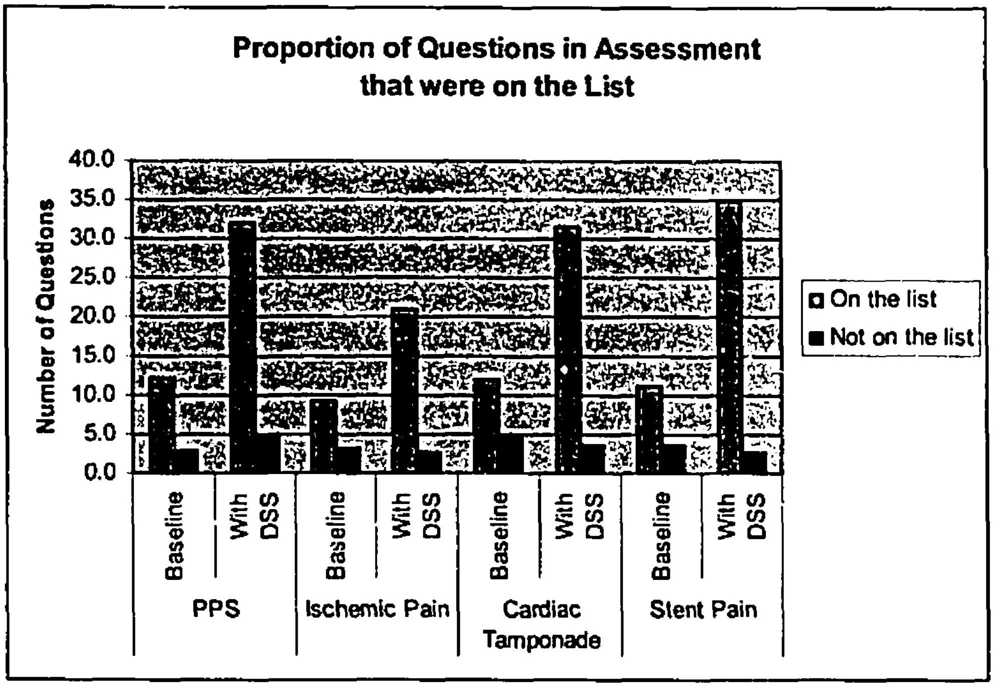


Figure 16: Proportion of Questions in Assessment that were on the List

A Wilcoxon Signed Ranks Test (Table 8) indicates that nurses asked significantly more questions on the list with the DSS than without, but there was no significant difference in the number of questions asked that were not on the list. Earlier, it was reported that assessment scores increased with DSS use. This supports the results we see here, since nurses asked more essential and beneficial assessment questions with the DSS than without it. So at the same time this figure refutes hypothesis (2), it helps confirm hypothesis (1) in that asking more essential and beneficial questions with the DSS contributed to participants' higher assessment scores.

		With DSS - Baseline
Questions on the list	Z	-2.366
	Asymp. Sig. (2-tailed)	.018
Questions not on the list	Z	-.085
	Asymp. Sig. (2-tailed)	.932

Table 8: Wilcoxon Signed Ranks Test, questions on the list and not on the list

Comfort

Participants' comfort with the DSS was assessed in the DSS test, on a line scale in the short questionnaire that followed each scenario. Figure 17 shows the level of comfort reported for each of the four scenarios, plotted by the serial order in which scenarios were presented. Thus, scenario 1 could represent any of the four scenarios. The figure shows that four of the seven nurses showed a slight increase in comfort as they progressed from the first scenario to the last. Note that they also reported the lowest comfort levels for the scenario presented first. For two nurses, the scores decreased slightly across the four scenarios, and scores for the remaining nurse remained constant throughout the test. The widest variation within participants was 20%.

One of the declining comfort lines belonged to Participant 2, the nurse who did not have the practice scenario before she began using the tool in the final test. Yet, all of her comfort scores were higher than the other participants' throughout, suggesting substantial individual differences in the ways the scale was used. Participant 5, whose comfort level stayed consistent, said after the first scenario that she wanted to talk faster than she could pull up questions. After the third scenario, she said "It's my comfort level with computers. I would just have to use it more." After the last scenario, she mentioned she was somewhat uncomfortable with assessing the patient and advising them to take medication. This discomfort arose because she was unsure of the usual NC protocol in these cases, and would explain why her comfort level did not change across scenarios. Participant 1's trend line is only slightly linear (R^2=0.158), but she commented after the second scenario that the tool was "easy to use." She did, however, feel "hindered at times" because she wanted to ask questions out of sequence. Following the third and fourth scenarios, she commented that she was experiencing trouble with the stylus. Both Participant 5 and Participant 1 indicated in their written comments that their comfort with the system could improve with time and use. These observations suggest that discomfort arose from several factors outside the DSS interface, as well as from the DSS itself.

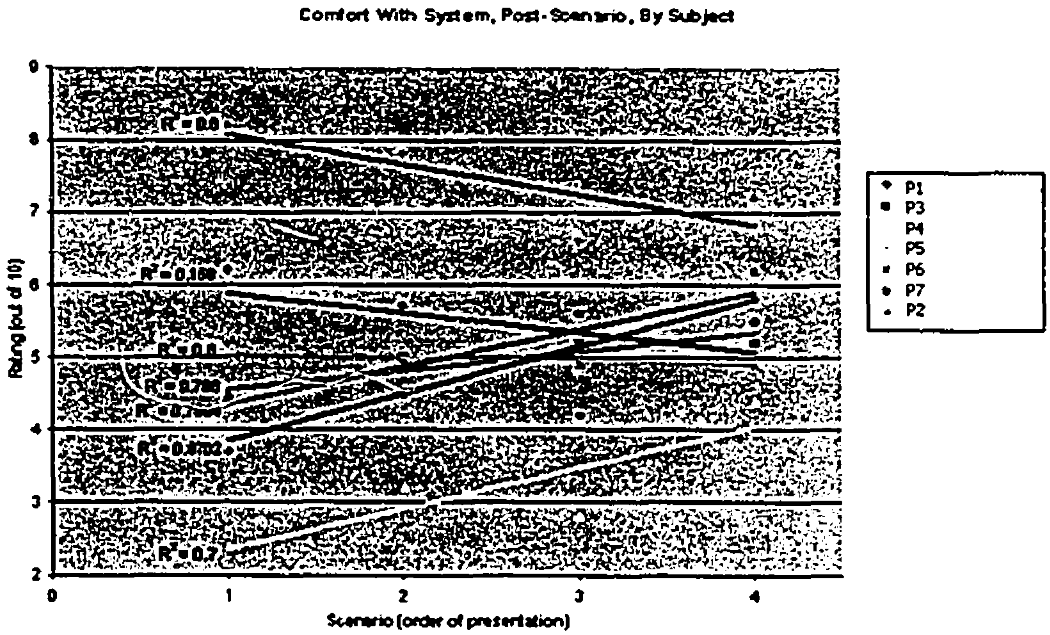


Figure 17: Comfort Level, Post-Scenario, by Participant

Looking at average comfort level by scenario order across participants in Figure 18, comfort appears to increase somewhat from the first to the last scenario.

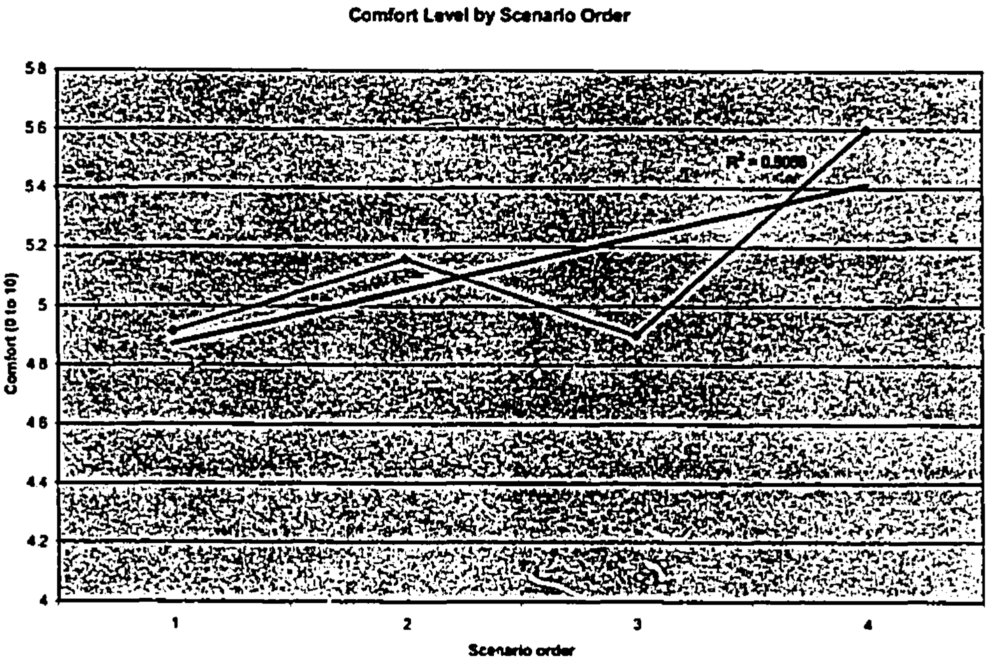


Figure 18: Comfort Level by Scenario Order

Satisfaction

Satisfaction data were analyzed in three ways to determine (1) how satisfied the nurses were with the DSS, (2) the extent to which satisfaction may be related to comfort, and (3) what aspects of the DSS were most and least satisfying.

(1) Overall satisfaction level

Figure 19 showing the average satisfaction scores and comfort scores for each nurse indicates that satisfaction scores ranged from 5.5 (P3) to 8.4 (P1) out of 10, with an average score of 6.7 thus, all scores were at least neutral, and these were somewhat higher for all nurses than their comfort scores. Both comfort and satisfaction were measured on line scales from 0 to 10.

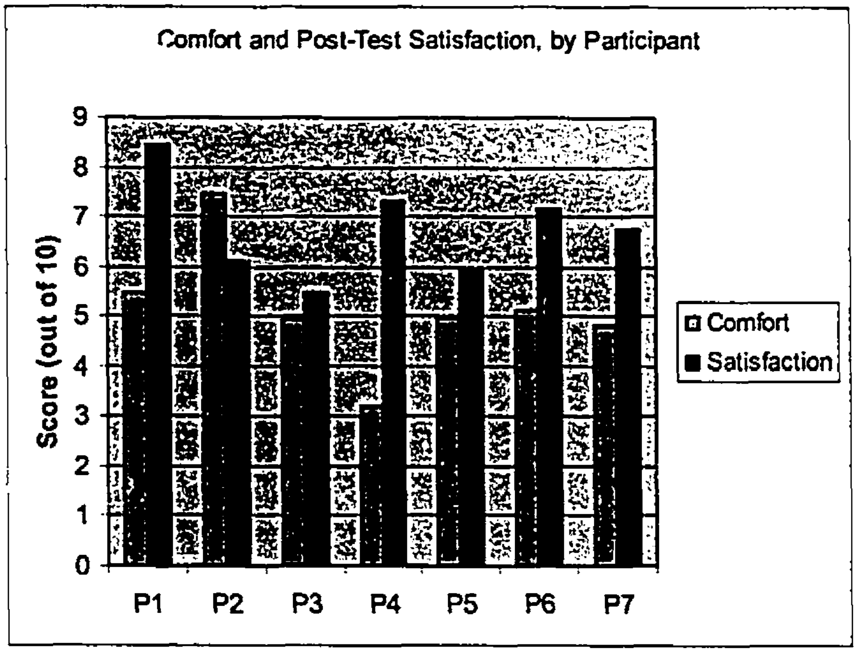


Figure 19: Comfort and Post-Test Satisfaction, by Participant

Aspects that ranked most satisfying (average scores across all participants):

- Q4 "It was easy to learn to use this system" – 7.5
- Q7 "The information was helpful to me in completing the scenarios" – 7.5
- Q15 "Overall, I am satisfied with this system" – 7.5
- Q2 "I could effectively complete the scenarios using this system" – 7.4

Aspects that ranked least satisfying:

- Q1 "Overall, I am satisfied with how easy it is to use this system" - 5.2
- Q6 "It was easy to find the information I needed" – 5.8

- Q9 "The order of the screens made sense" – 6.1

Deviation from the Algorithms

Deviation from the algorithms was measured by comparing the transcripts to the mid-fidelity prototype path. Since screen order is based on the flow of the pain algorithms, this screen order was used to determine differences in the participants' and the algorithm designers' mental models of the ideal course of assessment. This differs from simply determining if the nurses' questions were on the list, in that it considers the order in which they asked these questions. Details about where nurses deviated from the DSS screens can be found in Appendix Y.

Nurses often strayed from the very first screen, "Presenting Problem." In the PPS scenario, P1, 2, 5, 6, and 7 all deviated from this first screen. Deviation from this screen in the other scenarios was as follows: Ischemic Pain: P4 and 5; Cardiac Tamponade: P2, 3, 5, 6; Stent Pain: P1, 4, 5, 6. In all cases of deviation from this screen, participants wanted to know more about the patient's pain right away – asking about onset, characteristics, or whether it had happened before. This is consistent with the patterns found in the baseline test. The nurses could have been probing for additional presenting problems, which would have fit this screen. However, the finer details of the patient's pain were not accommodated at this point in the DSS. Unless it is deemed contradictory to best practices, a change in the tool might be advisable to accommodate this behaviour.

In the PPS scenario, P2 and 6 anticipated the medication screen, asking about the patient's drugs one screen before the prototype presented it. In the Ischemic Pain scenario, P2 and 5 skipped the final screen altogether in favour of ending the call and instructing the patient to call 911. These participants felt they had enough information at this point to know the patient needed urgent help.

Deviations occurring toward the end of the scenarios that involved asking questions (rather than skipping over parts), tended to be where participants wanted to ask a question that was not present in the prototype. For example, in the Cardiac Tamponade scenario, P3 asked about blood pressure equipment. In the Stent Pain scenario, P2 asked how many support pillows the patient needed to remain comfortable. Both of these occurred at the last screen.

These deviations from the prescribed sequence of questioning in the DSS suggest that the nurses' mental models do not fit exactly with those of the experts who developed the algorithm sequence.

Comments on T3 Hardware

Overall, it appeared that the participants were very interested in the T3 hardware, and they were keen to see what it could do. An observation across participants was that most of them needed to be reminded they could slide open the T3 screen. The extra screen room was universally appreciated once it was revealed. Two participants found it difficult to return to where they had been, if they accidentally clicked something that brought them elsewhere.

Comments included:

- "Would have to see if it would be too small/niggly during a call"

- "Presumably we would get an 'in-service' [professional development course] to learn to use it, like with other apps?"
- "Find the skinny stylus awkward… prefer fatter pens"
- "I won't click on anything else. I'll do whatever someone shows me to, but I'm afraid of breaking something."
- "I prefer a hard case, in case I drop it"
- "Harder on the tablet because my arm is up in the air" → participant was assured that she could rest her arm on the tablet and not break it, but she seemed unsure
- "Would love to be able to speak, and have stuff auto-recorded into a database"
- "I think the learning curve would be a little steep, especially for older nurses"
- "It should be easy to erase mistakes"
- "If I had to write a certain way (i.e. Graffiti), I think typing would be easier" → referring to the on-screen keyboard

And finally, one participant asked "Can I get one of these for participating?" suggesting this participant was eager to start using the T3 device.

Discussion

The purpose of this research was to design an effective handheld decision support system that provides access to best practices for cardiac teletriage. The outcome of this design, and observations on the processes used to create it, are discussed below. A description of the contributions and limitations of this study and a summary of conclusions complete this section.

Effectiveness of the Design: Summary of Main Findings

Assessment and Recommendation Quality

Hypothesis (1a) stating that that nurses' performance in assessment would improve with the DSS was supported. Quality of assessment scores showed a significant improvement across all scenarios. Assessment quality was measured by the quality of questions asked by the nurse, but it was apparent that nurses were making decisions about recommendations based on factors other than the answers to these questions. In the cardiac tamponade scenario, three out of seven participants commented that the patient "didn't sound like they were in distress." Despite asking the right questions, the participants did not come to the correct conclusion of cardiac tamponade. This underscores the notion that nurses are acting not only from the answers they get from the patient, but from other cues such as tone of voice. Regardless of the patient's tone, the nurse should be acting on the information they are given. By the time a patient is audibly in distress, it could be too late to intervene successfully.

There was no significant difference in recommendation quality with the DSS, therefore hypothesis (1b) stating that recommendation performance would improve with the DSS was not supported. The reliance on other cues, mentioned above, could explain why improved assessment scores did not lead to a subsequent improvement in recommendation quality.

Part of the absence of improvement in recommendation performance may be attributable to the fact that desirable assessment questions were presented directly in the DSS screens during this test, while the recommendations were not. Having the essential and desirable questions in front of them on the DSS would make the nurse more likely to ask them. Measurement of the tool's capacity to improve the accuracy of assessment and recommendations was conservative, in that the participants were asked to deliver their assessment and advice based solely on the answers they'd received from the patient. In the final tool, the system will throw a "flag" screen when it has enough information based on the input from the nurse to suggest what the patient's condition might be, and to give associated recommendations. During the test, nurses were permitted to see this automated pop-up "flag" only after they had presented their own conclusion and recommendations.

The scenarios where participants scored best on their own recommendations, Ischemic Pain and Stent Pain (see Figure 11, "Quality of Recommendations, by Scenario"), were the same ones for which they were more likely to agree with the DSS assessment. The scenario with the least amount of agreement (3 out of 7 nurses), PPS, fared worst in terms of Quality of Recommendations scores. A possible reason for this is that participants had less reason to doubt the DSS if it agreed with their own recommended advice. In the PPS scenario, two participants who disagreed with or were not sure of the auto-assessment had never heard of PPS. This suggests that nurses would not blindly follow the recommendations of a DSS if those contradicted their own conclusions. This would be an important safety consideration, in that if a nurse did not record all relevant information in the DSS or made an error in entering a choice, the resulting automated assessment might not be accurate.

It is recommended that the DSS be evaluated in the future with the automated pop-up screens available to the nurses during the test. This would give a more accurate picture of the impact of full DSS functionality on recommendation quality.

Hypothesis (2) stating that participants would ask fewer questions with the DSS than without it was refuted. Participants were actually found to ask more questions with the DSS than without it. However, most of these additional questions were on the list of essential or beneficial ones for a good assessment, and contributed to higher assessment scores. In fact, in conversation with one of the SMEs after the study had begun, a senior NC mentioned that experienced NCs typically ask more questions than the novice NCs. If this is the case, an increase in the number of questions asked with the DSS, compared to without, would be desirable for those who are inexperienced in teletriage. Indeed, the additional questions asked were shown to be of good quality. In this respect, hypothesis (2) turned out to be misguided; it should have predicted an increase rather than a decrease in the number of questions asked, provided that additional questions asked could be shown to be relevant and beneficial to the final recommendation.

The scoring lists of essential and beneficial questions were iterated during the course of this research, and it is possible that there could be other beneficial questions that have not yet been considered. For this reason, questions not on the list were not labeled detrimental or of poor quality, but simply were not counted toward the score.

Users' Comfort With the DSS

In general, users' comfort with the DSS increased from the first presented scenario to the last. One participant indicated that the discomfort they were feeling was not entirely related to the DSS, but to the role they were playing and the associated experimental environment. Additionally, one participant was uncomfortable due to unfamiliarity with NC protocols for giving medication advice over the phone. Some participants expressed discomfort at not having a pen and paper, their normal tools, available to them during the test. The only participant whose comfort score was higher than her satisfaction score was P1, who had a slightly different presentation of the DSS. She had access to a pen and paper during the test, and she did not have a practice scenario before the pain scenarios. The availability of pen and paper could have made her feel more comfortable in general compared to the other nurses. Four participants commented they felt the tool would become easier with use with increased practice, which suggests that comfort levels could rise in the longer term.

Satisfaction

Satisfaction ratings for the DSS were all better than neutral. The highest scoring elements were "easy to learn" and "the information was helpful" (7.5). Interestingly, the lowest scoring element was "easy to use" (5.2). These ratings suggest that with use, overall satisfaction with the system will improve. That the users find the system easy to learn and helpful to them bodes well for the future adoption of this tool.

Observations on the DSS Design Process

User Centered Design

This research did not compare designs done with and without the benefit of a user centered design process. Therefore it is impossible to say whether user centered design led to a better design than would have been generated otherwise. However, use of such a process in this research was beneficial in three ways. First, the end product, a mid-fidelity prototype tool, increased participants' teletriage assessment quality and was received with positive levels of satisfaction. Second, the researcher created and documented a new type of diagram for interpretation of workflows and coordination of design ideas. Third, the entire process was documented so that it may be repeated or referred to in the future. In the literature, there is no record of past design processes or interaction strategies in medical DSS development.

Pain Algorithms

The pain algorithms were difficult and time-consuming to produce, requiring significant commitments of time and effort from a team of busy experts. Since these were not tested prior to use, it may be that they require adjustment before the final DSS tool is implemented. In particular, nurses were observed to probe for pain details immediately after determining a patient's main complaint, rather than getting the patient's history as per the prescribed DSS sequence. There is evidence in the literature that a weakness in some teletriage environments is the failure of healthcare workers to adequately determine the patient's history. However, the algorithm sequence could be adjusted to move this information back a screen or two in the DSS, to accommodate the nurses' desire to know more about the patient's pain sooner.

Hierarchical Task Analysis

Hierarchical task analysis was employed to analyze NCs' tasks and goals in the context of the DSS system. Though HTA was the closest fit to this application when compared to other kinds of constraint-based and traditional task analysis, it was not a perfect solution.

The product of the analysis, the HTA diagram, did not describe the tasks and goals sufficiently to inform detailed design decisions. It did not appear that the re-description of goals into subgoals and plans carried far enough to show enough detail about what the system would do. Perhaps such re-description of goals could be improved by generating the HTA diagram as a collaborative effort involving the expert users rather than being generated by a single researcher.

The abstract nature of this type of diagram, describing a general scenario rather than a specific one, necessitated further thinking to adjust it to the four pain scenarios before a prototype could be developed. This gap between task analysis and design is recognized explicitly in the literature, though little is offered in the way of a workable solution. One helpful addition to the process turned out to be common level diagrams. These are described below.

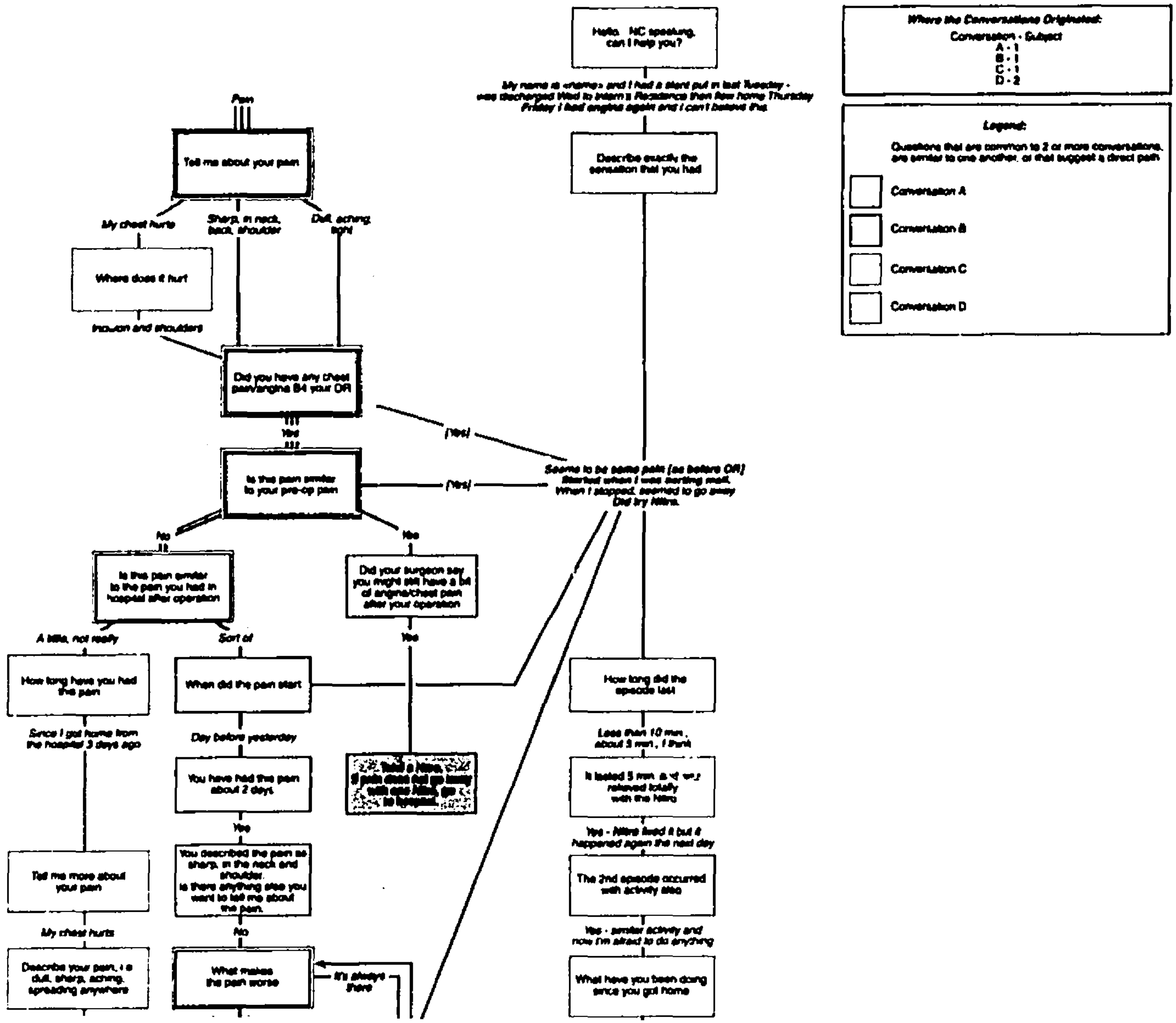
Common Level Diagrams

Originally, the idea for a common level diagram arose from the need to interpret workflows provided in the preliminary data, and to relate these workflows to each other.

These workflows described telephone conversations, and some were submitted in handwritten form. It was very difficult to pick out similarities in content and structure of these workflows without summarizing them in some cohesive way. By representing this summary visually, a common level diagram allows the reader to immediately see where these workflows differ and where they are similar. This type of diagram is superior to a typical flow diagram, which might be used to represent individual workflows, in that it clearly indicates areas of commonality in both sequence and content.

Figure 20 gives an example of a common level diagram in this context, showing similarities between four typical pain-related phone calls as described by the NCs. This data was collected from the NCs prior to the present research, via the Call Scenario Templates (Appendix B). NCs' questions appear in boxes, and patients' answers appear between them. Coloured outlines and joining lines distinguish the individual conversations from each other, and show where they overlap. Arrows show the direction of flow. Gray boxes indicate questions that are common to two or more conversations, or are similar to one another. Solid coloured shapes indicate termination points, where the main task (in this case, the telephone call) comes to an end. This diagram helped inform the task analysis, as it highlighted common points in the workflow and suggested a pattern of progression through the questioning.

Conversations Between NCs and Surgery Patients – Pain



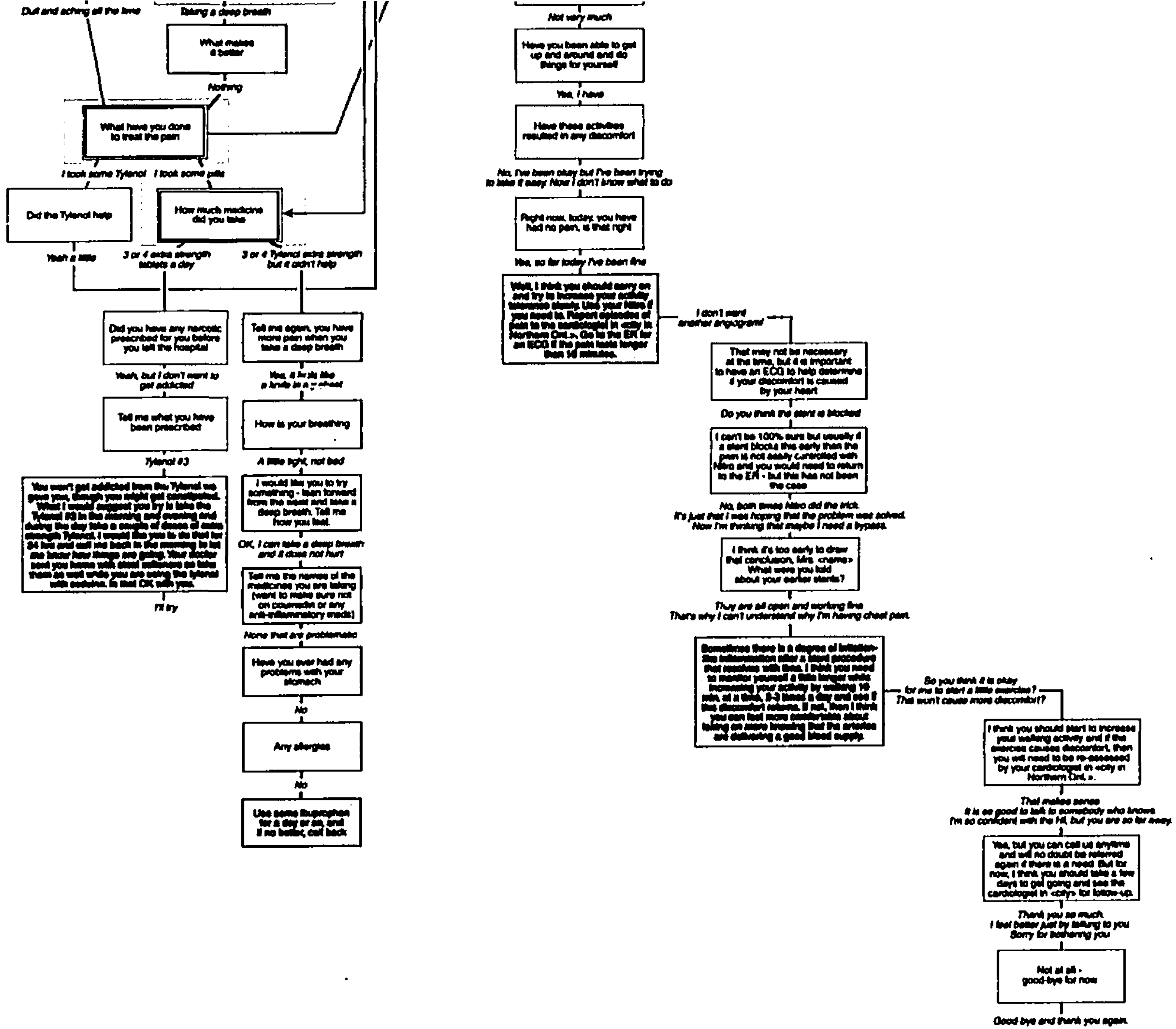


Figure 20: Common Level Diagram, interpreting workflows

Following the task analysis, it became apparent that common level diagramming could be used again – as a storyboarding technique to bridge the gap between the hierarchical task analysis and the actual interface design. HTA diagrams, while effective in summarizing task flow for a very general case, are just that – general. Prototypes are designed with a very specific path through the interface, based on certain interactions between the user and that interface. Therefore, the designer must make the leap from the HTA diagram to the storyboard scenario they're developing. The common level diagram was used in this case to lay out each scenario in a clear sequence, recalling information from the HTA diagram to ensure that the desired task flow was not violated.

In the early stages of interface design following a task analysis, common level diagrams list concrete steps of particular scenarios in a way that is easy to translate into interface structure. The common level diagram does not describe every possible interaction in the interface, but rather acts as a storyboard for several scenarios in parallel. By showing how the sequence for each scenario plays out, the common elements between scenarios become apparent (Figure 21). This diagram shows complete paths for each scenario, with assessment questions in boxes and patient responses in italics. This eased the transition in developing the first paper prototype.

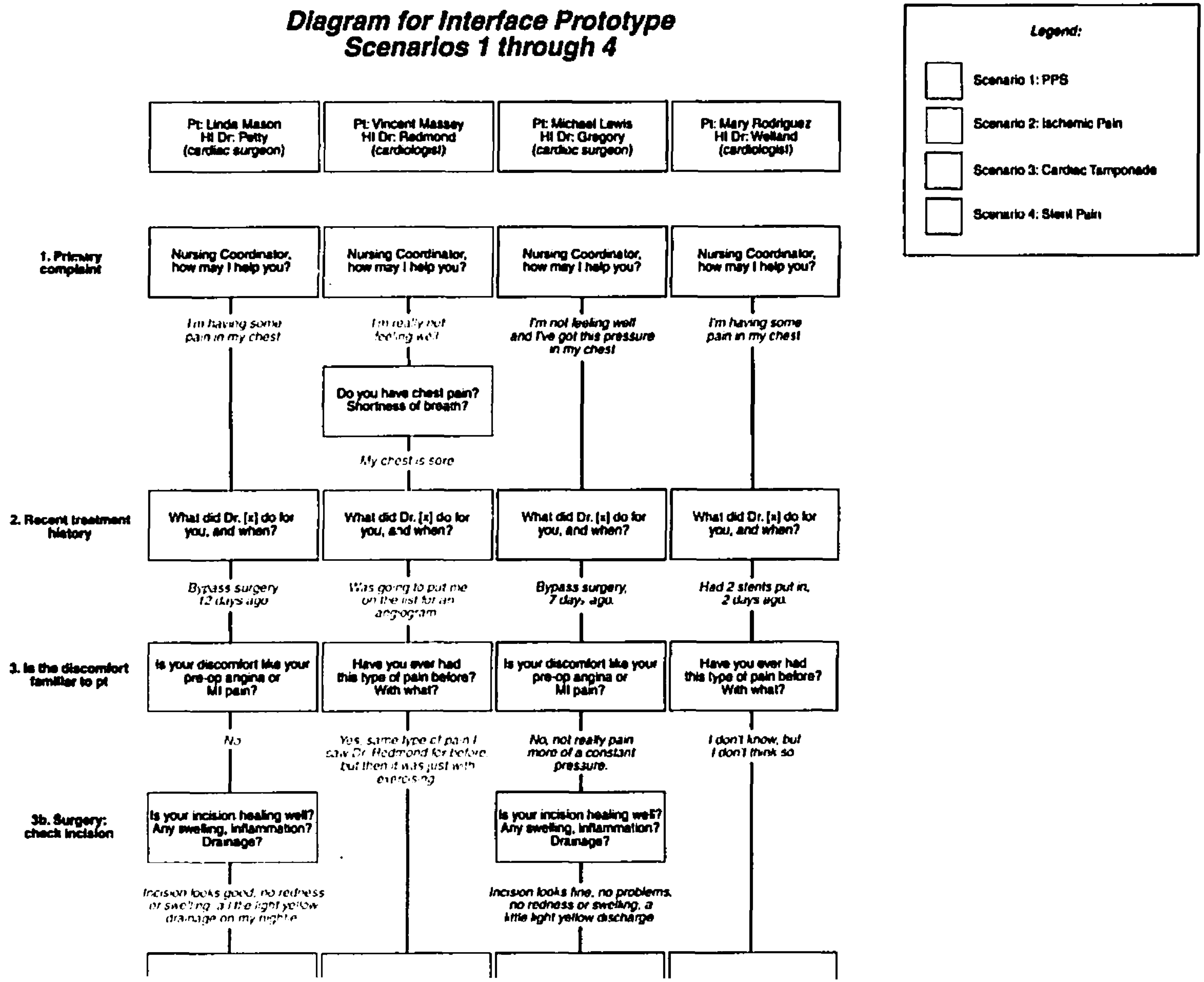


Diagram for Interface Prototype
Scenarios 1 through 4
Legend:
Scenario 1: PPS
Scenario 2: Ischemic Pain
Scenario 3: Cardiac Tamponade
Scenario 4: Silent Pain
Pt: Linda Mason
HI Dr: Petty
(cardiac surgeon)
Pt: Vincent Massey
HI Dr: Redmond
(cardiologist)
Pt: Michael Lewis
HI Dr: Gregory
(cardiac surgeon)
Pt: Mary Rodriguez
HI Dr: Welland
(cardiologist)
1. Primary complaint
Nursing Coordinator, how may I help you?
I'm having some pain in my chest
I'm really not feeling well
I'm not feeling well and I've got this pressure in my chest
Do you have chest pain? Shortness of breath?
My chest is sore
2. Recent treatment history
What did Dr. [x] do for you, and when?
Bypass surgery 12 days ago
Was going to put me on the list for an angiogram
Bypass surgery, 7 days ago.
Had 2 stents put in, 2 days ago.
3. Is the discomfort familiar to pt
Is your discomfort like your pre-op angina or MI pain?
Have you ever had this type of pain before? With what?
No
Yes, same type of pain I saw Dr. Redmond for before, but then it was just with exercising
No, not really pain more of a constant pressure.
I don't know, but I don't think so
3b. Surgery: check incision
Is your incision healing well? Any swelling, inflammation? Drainage?
Incision looks good, no redness or swelling, a little light yellow drainage on my nightie
Incision looks fine, no problems, no redness or swelling, a little light yellow discharge

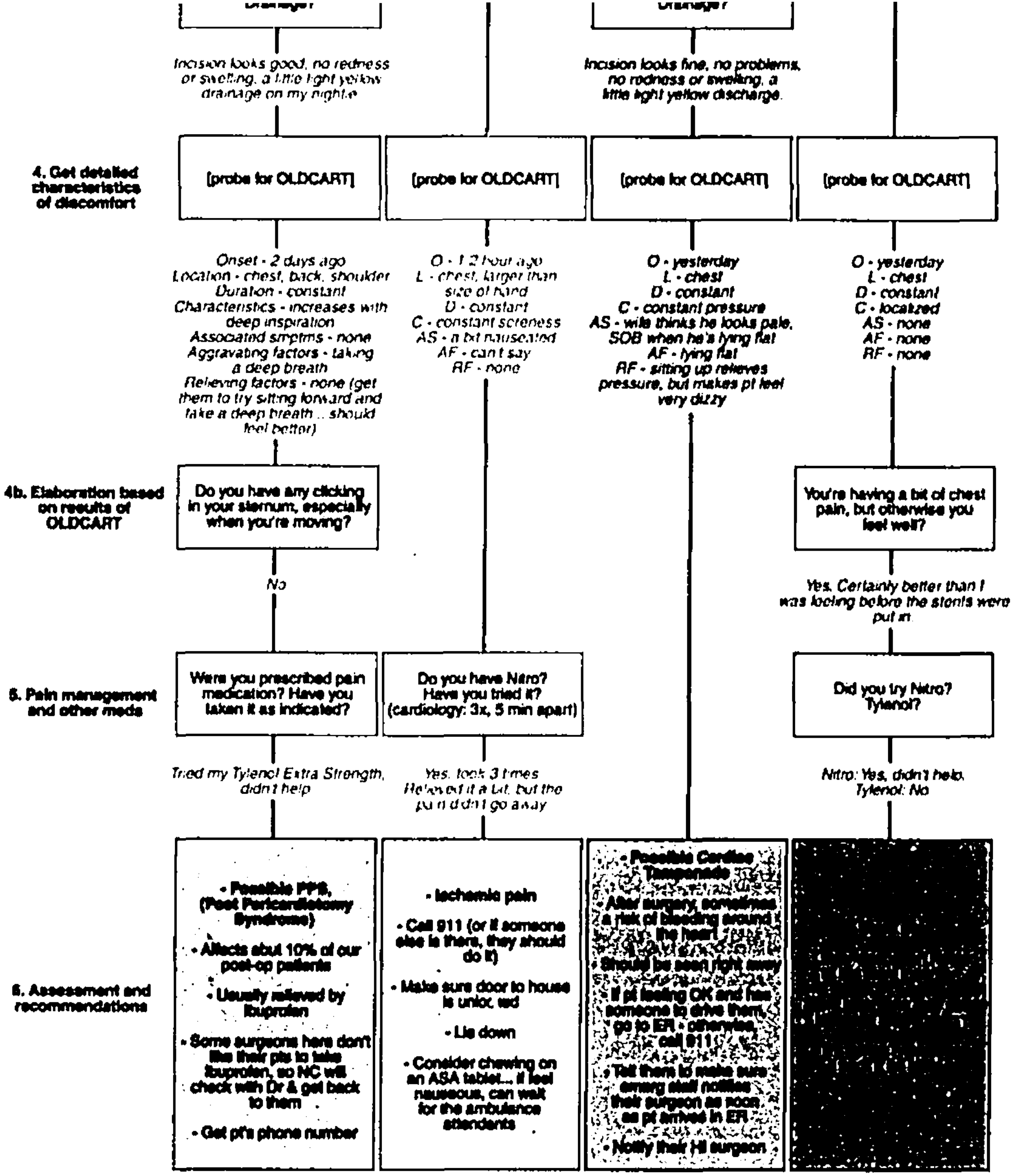


Figure 21: Common Level Diagram, as storyboard for prototype

Attempts to use hard copies of the common level diagrams during the usability test enabling the facilitator to note deviations from the optimal path during the course of each pain scenario turned out to be impractical due to the need to observe and record other behaviours and comments at the same time. Thus, the main benefits of the common level diagram in this research were: interpreting workflows from the preliminary data, acting as a bridge between the HTA and interface design, and providing a design artifact that can be referred to by the client, or in this case the DSS development team.

General Observations

The participants were floor nurses, who were quite uncomfortable with answering patient's questions, and in offering assessments of a patient's condition, over the phone. Neither is part of their normal job duties. In fact, floor nurses are explicitly forbidden to do either of those things. They refer any call-in patients to the NCs. Comments from the participants suggested one reason for them feeling so uncomfortable is that the visual cues they normally get from seeing a patient on the ward were conspicuously absent in a phone call situation, as was the patient's chart. The participants also appeared distracted by the DSS at times, and some commented that it was difficult to try to attend to it while conversing with the patient on the phone. With increased experience with the DSS, this problem would most likely diminish.

The standardized patient profiles used in the pain scenarios worked very well. Updating the patients' characteristics as the experiment progressed, adding new ones as nurses' questions probed for them, allowed the SME acting in the role of the patient to answer questions consistently through the entire experiment. These profiles went through considerable iteration, suggesting that further revision may be required to arrive at a complete description of each pain complaint. The disadvantage to not starting the experiment with a vetted patient profile was that the SME acting in the role of patient was put on the spot when a nurse asked a question the answer to which was not on the existing list of characteristics. One change that might be considered in the current patient profiles would be to add fever to the characteristics for PPS. It was originally omitted to avoid flu-like symptoms that might throw the nurses off the right assessment track.

The list of questions determined by the SMEs to be essential or beneficial to a sound assessment for each pain scenario could also be used in training teletriage practitioners, and in refining the existing algorithms. In terms of design implications, having this scoring system in place prior to the design could have a positive influence, in that it would underscore the most important pieces of the assessment and recommendations. These critical elements could then be given greater emphasis in the DSS.

Design Recommendations

A few problems were noted consistently in the usability test, some of which are correctable within the interface, and some of which are related more to the environment around use of the tool.

Screen contents: Because the practitioner is dividing their attention between the patient on the phone and the DSS, improvements should be made to make sure attention is focused on the most important contents of each screen for a given situation. Some participants claimed they felt slow on the DSS, and this focus would help them attend to the most critical questions right away. For example, though we will not want to restrict access to the full list of OLDCAR choices, those that are most pertinent to the case at hand – based on summary of responses so far – could be bolded to allow the nurse to easily scan to them. Another possibility would be to re-order the presentation of these checklists, depending on context. However, reordering lists dynamically will reduce the predictability of where items are located on the screen once the practitioner is more familiar with the tool. This lack of predictability could create an even greater impediment. Therefore, reordering the lists, thereby violating the design principle of consistency, is not recommended as a means to prioritize list items.

Participants were occasionally observed entering choices that appeared to be accidental. In the case of "Is the incision healing well?" with a "yes/no" answer option, one participant asked a series of questions to determine if the incision was healing well. These questions were prompted by a list of characteristics in the DSS, under the "More Info" pop-up for this screen (Figure 22).

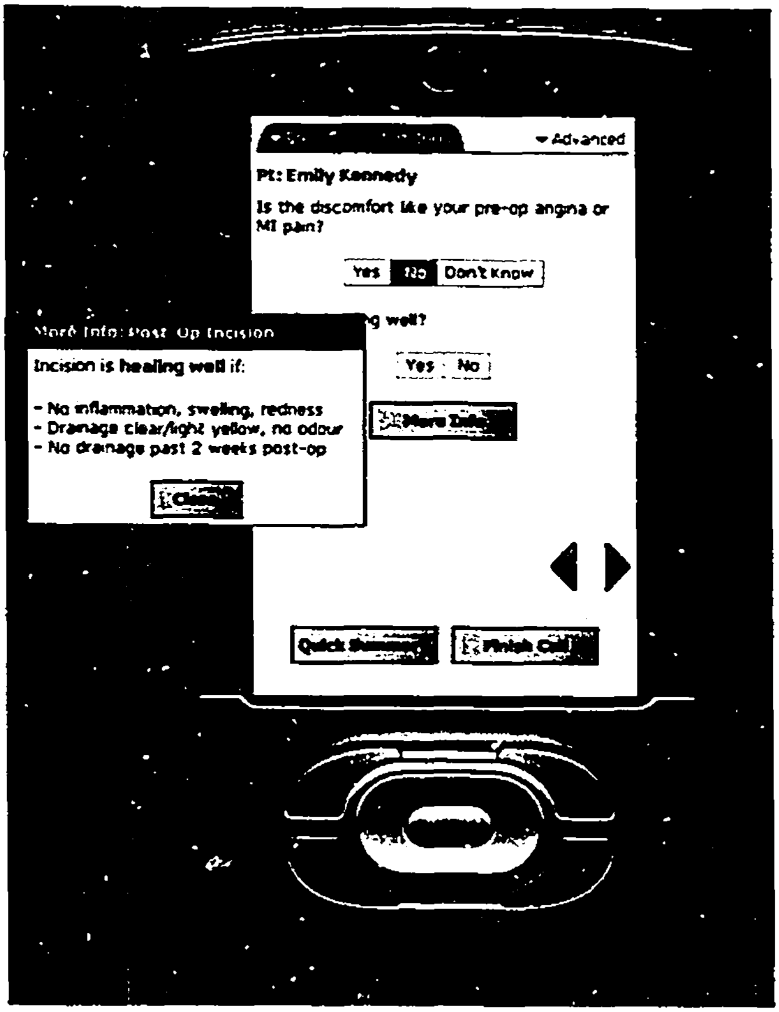


Figure 22: Previous Discomfort/Incision Screen

The patient answered each question with a "no" – for instance, is there any swelling or redness – indicating that the incision was fine. In response, the participant entered "No" in the interface. It appeared that the participant was thinking "no problems with the incision" rather than "yes, the incision is healing well." For the next iteration of the prototype, this item might be worded more naturally as "Any serious incisional problems?" to which the nurse could answer "no" if the patient answered "no" in response to a potential list of concerns.

Certain interface elements were used out of functional necessity in the prototype, rather than by design choice. These elements merit further thought as they are translated to the Palm environment. For example, lists allowing multiple selections had to be coded with checkboxes in dhtml layers to let participants make multiple selections in the tablet browser environment. The menu showing previously visited screens was also rendered in a layer, and required a button to dismiss it if the user did not click on one of the list items. In a fully-functional environment, simply clicking outside a list would dismiss it if one declined to make a selection from it. This simpler interaction is preferred wherever possible in the final tool.

Two participants commented that they would like the ability to jot notes down as they are talking to the patient. If the NCs agree that this is a desirable feature, it would be advisable to include a hideable notes area at the bottom of the screen. This area could be expanded for use or collapsed to give more room to the rest of the screen contents. Contents of the notes area would persist throughout the screens, and would be saved in the DSS as part of the call session.

Screen order: Some nurses felt the order of screens was unnatural for them. This was evidenced by the fact that they sometimes strayed from the questions in the prototype screens. The results indicate that nurses strayed most at the second screen (Presenting Problem), wanting to find out more about the patient's pain before determining the nature and timing of their most recent UOHI procedure. Interestingly, this supports the literature, as Wheeler (1993) observed that practitioners frequently gave advice without obtaining adequate histories in a teletriage environment.

The fact that the participants strayed most at the second screen – which was really the first screen they interacted with – could indicate that they were unsure of what would come on the next screen, and they did not want to be distracted from what they felt was the most logical line of questioning for them. This would indicate that they felt the DSS tool was in their way.

This issue could be handled in a couple of different ways. The algorithm could be reviewed, the screens could be moved, or the DSS users could be trained to use the Advanced feature in the tool. The Advanced feature, not implemented in the prototype, allows the practitioner to jump to any screen in the tool at any time, thus giving them more options than just the forward and back buttons.

Additional functionality: Two participants were not familiar with Post Pericardiotomy Syndrome, the ailment in one of the pain scenarios. The addition of a glossary of terms, accessible via links in the DSS, might help users who are unfamiliar with a term that they see on an automated assessment flag. Already included in the prototype was an example of a More Info button, which could be more widely used in the DSS. The button in the prototype led to detailed criteria of "incision healing well." Additional More Info buttons should be implemented where elaboration of the screen content may be required.

Call disposition and patient information screens were developed as part of the complete mid-fidelity prototype (Figures 23 through 25), but were not tested as they did not help in measuring assessment or advice quality. However, in the final implemented DSS, these screens will be important in allowing the NCs to record details of the patient call.

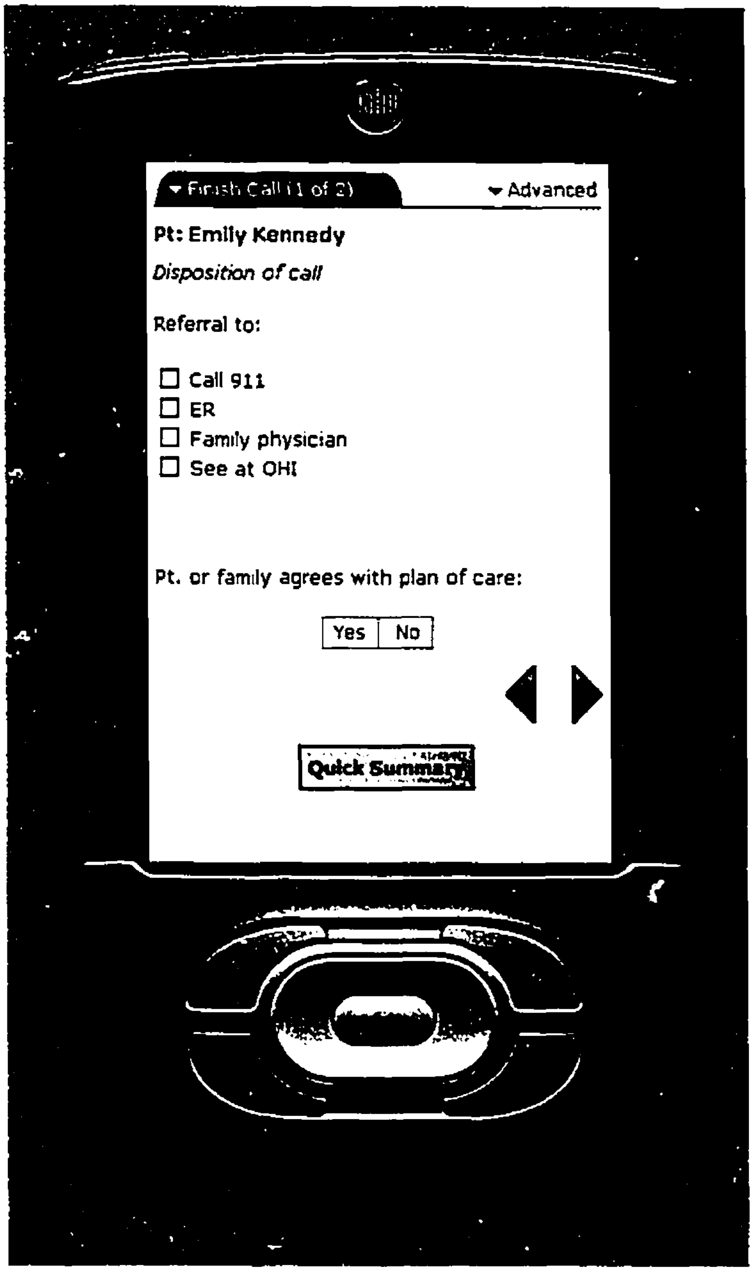


Figure 23: Mid-Fidelity Prototype – Finish Call (1 of 2)

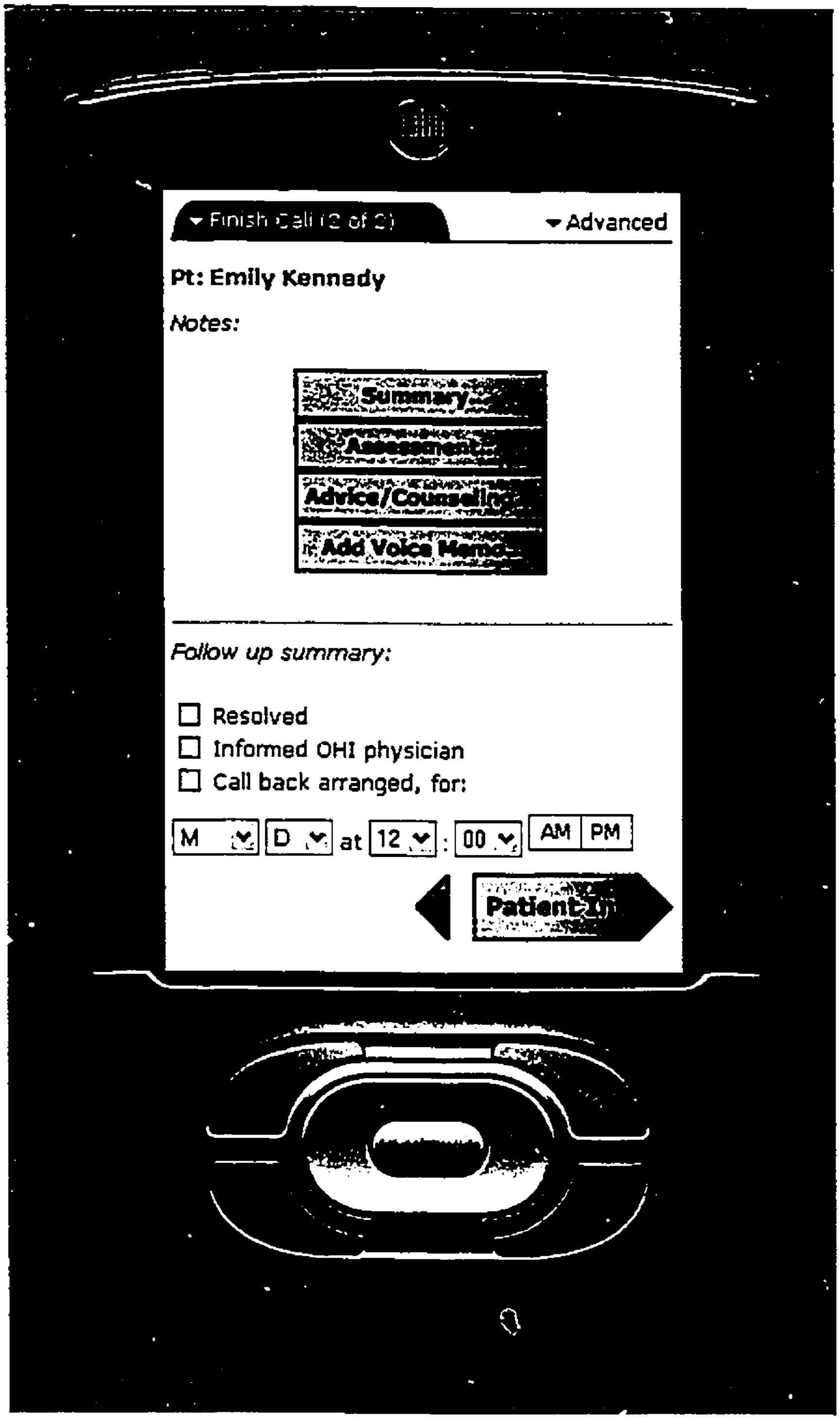


Figure 24: Mid-Fidelity Prototype – Finish Call (2 of 2)

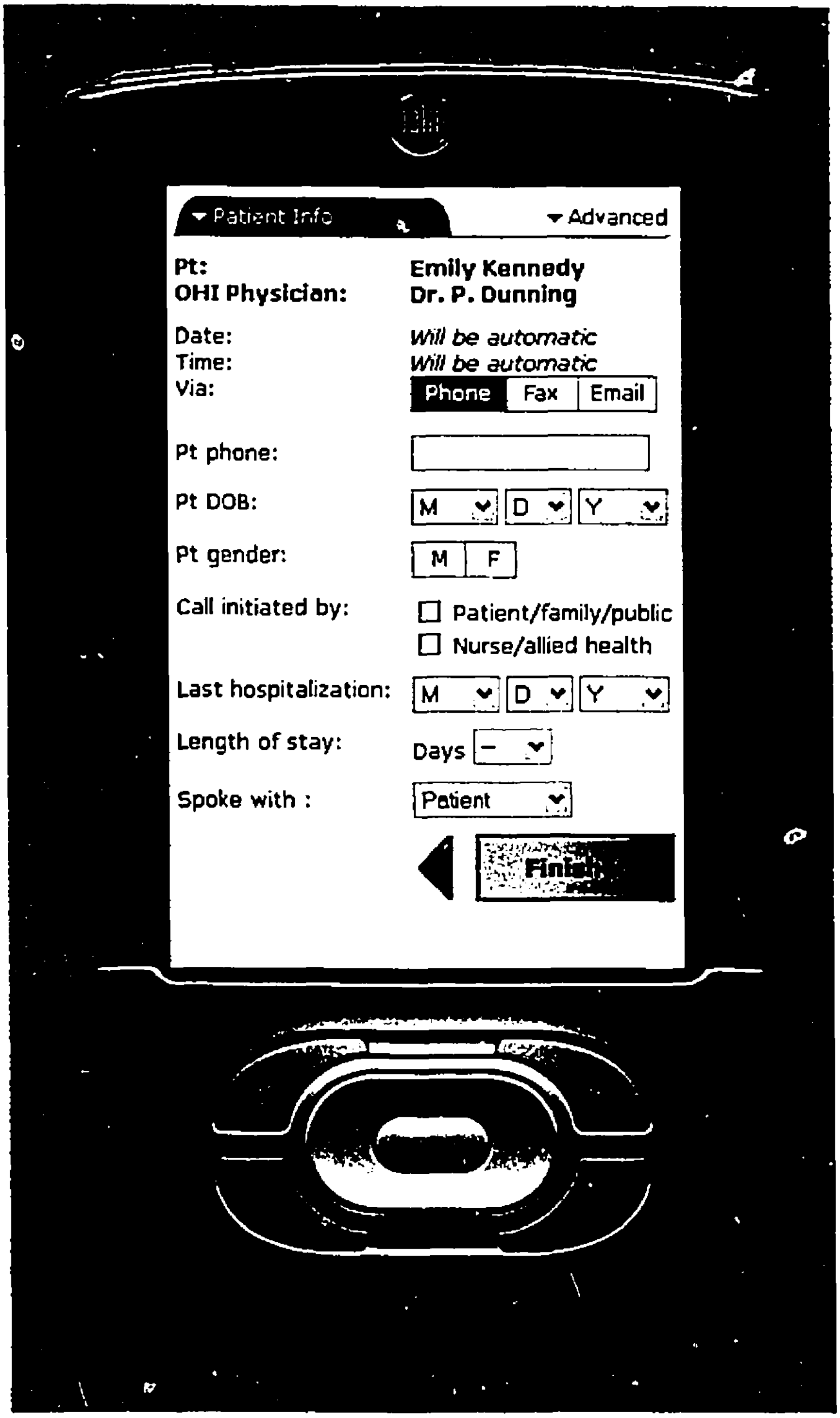


Figure 25: Mid-Fidelity Prototype – Patient Info

Training: The strongest recommendation for overall implementation would be to develop a short training tutorial for those who will be using the tool. Ideally, this tutorial would be contained within the DSS on the T3, so the users could access it whenever their busy schedule allows. Additionally, an introduction screen – which was not included in the prototype evaluation – could be a beneficial addition (Figure 26). The first time the user launches the application, they would be greeted by this screen. It would give them a quick summary of what they can do with the tool, and how they can quickly end a call if the patient is in distress. A checkbox would allow the user to dismiss this screen for all future application launches. They could return to the introduction screen at any time after that by clicking "About This Tool" in the opening screen.

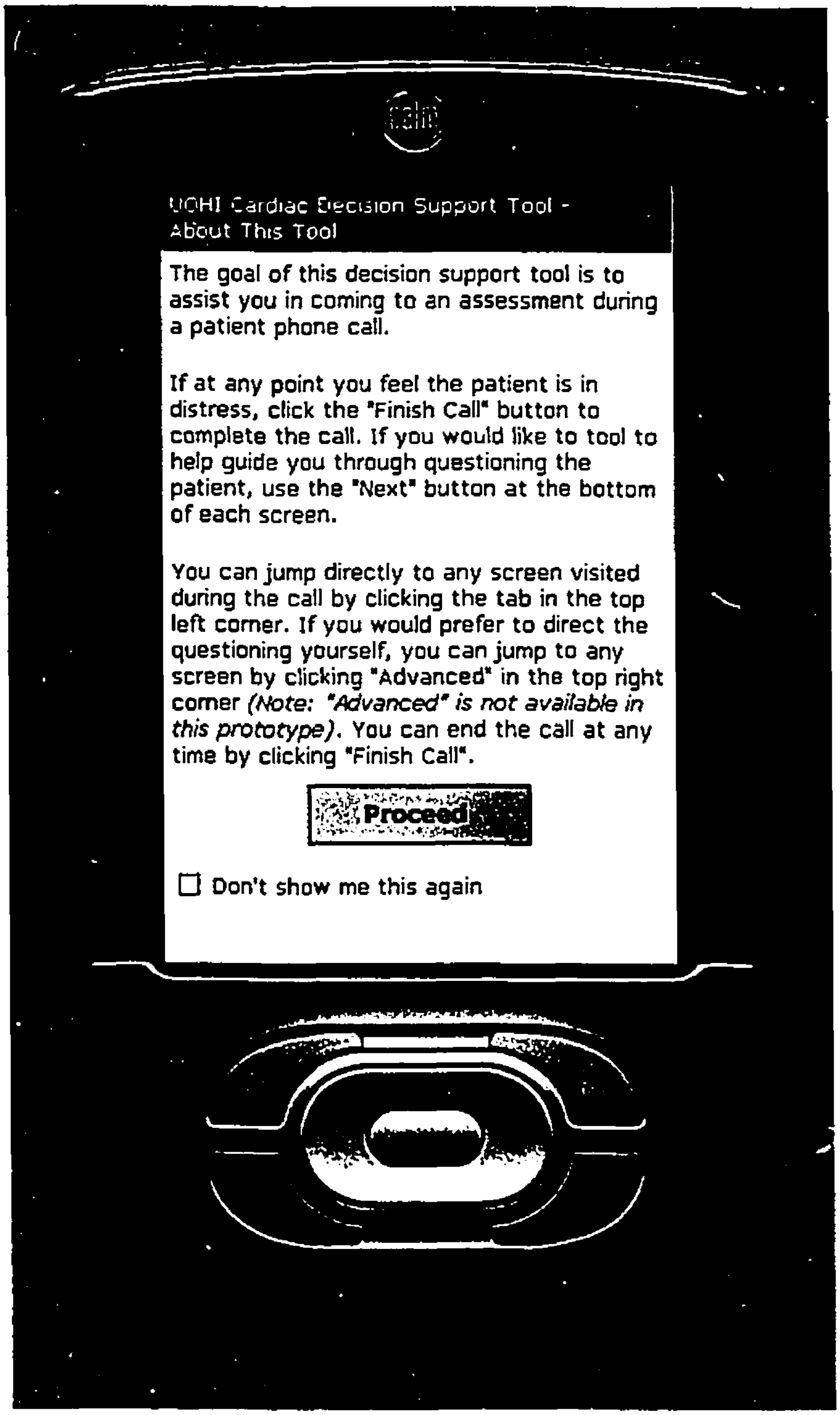


Figure 26: Mid-Fidelity Prototype – Introductory Screen

The DSS could be introduced into the training of new NCs as they are being trained on the job by the experienced NCs. New hires could be encouraged to walk through the tool as the experienced NC plays the role of the patient, as was done in this study. To ease the burden on the NCs to think up scenarios, they could be provided with the standardized patient scenarios we used for this thesis.

Limitations

Generalization of these results is limited, due in part to the small sample size. Because of the highly specialized and variable nature of the data in this study, SMEs were used extensively not only in developing scenarios, but also in coding and scoring the data. This process is time consuming, and was in this case iterative, as the SMEs refined their scoring criteria. Additionally, decisions had to be made about how to treat ambiguous or repetitive questions. It was decided, for example, that in an exchange like the following:

- "Is this like your pre-op pain?"
- "No."
- "Not at all, eh."
- "No."

the phrase "Not at all, eh." would not count as a question. Questions that were repeated counted as separate questions.

Unfortunately, it was impossible to test the algorithms prior to using them in this study, even though they had been rigorously developed and approved by experts. Places where nurses commonly strayed from the prescribed algorithm could be noted as possible points of modification to the existing algorithms.

Though the mid-fidelity prototype was very flexible in allowing nurses to enter whatever they wanted, it was not coded to summarize every possible answer. The control that invokes a pop-up checkbox list is supposed to display the items entered – usually in truncated format – after the user closes that list (see Figure 27).

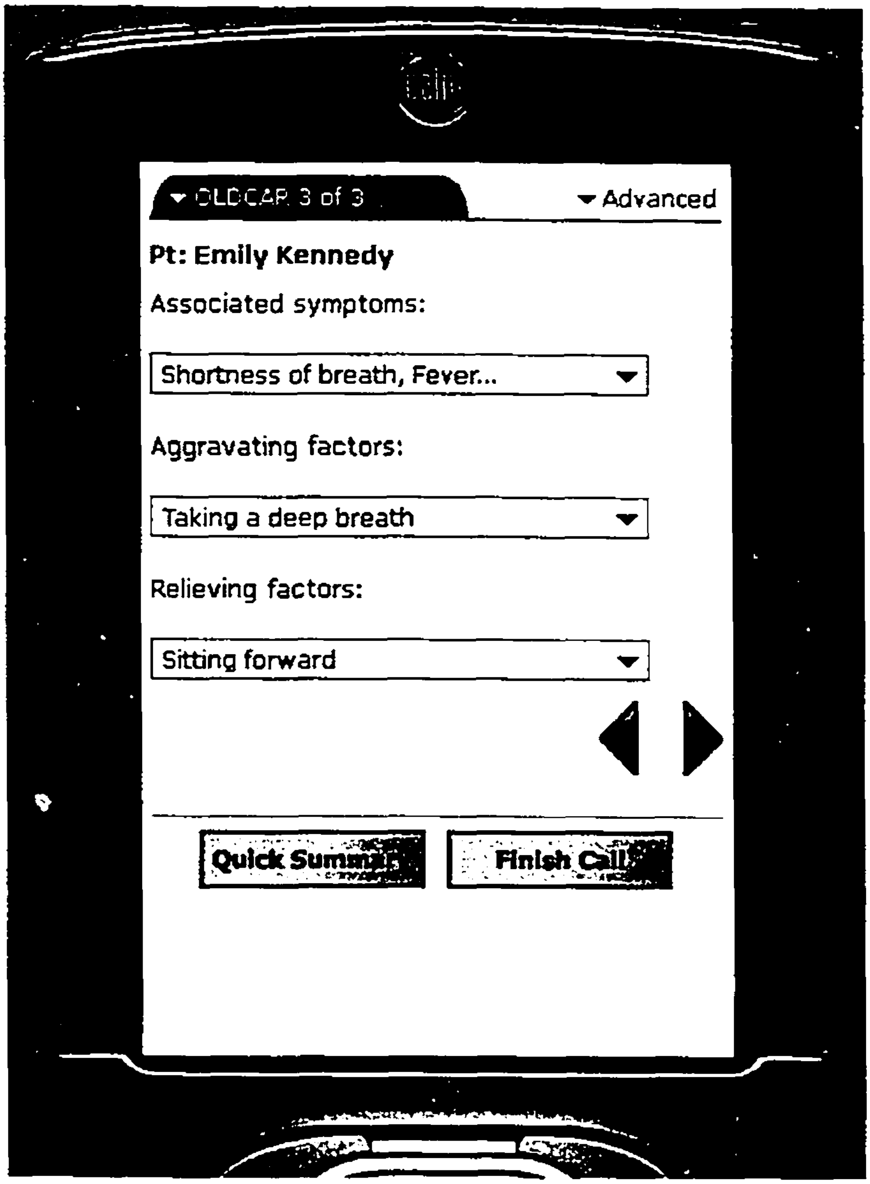


Figure 27: Mid-Fidelity Prototype – Simulated Dropdown Menus

In the prototype, the control was populated with the answers the patient would give in response to the questions on the list, once the list was closed, had the nurse asked about everything on the list. Most of the time, this corresponded to the nurse's input during the test. However, sometimes the nurses did not ask about every item, and things would appear in the "dismissed" list that they had not checked off. Interestingly, the nurses did not seem to notice this, as not one of them commented on it.

Future Research

One problem identified with the current Telepractice Record form was that NCs tend to fill them out incompletely. Though this is unlikely to make a difference in the quality of their advice or assessment, this tendency creates difficulties in record keeping and patient tracking. It would be interesting to study whether enabling NCs to enter patient information in the DSS affects how complete the records are when they turn them in. Since the DSS will be associated with a database collecting patient call information, the potential is there to significantly improve record keeping for patient calls.

Developing the prototype for the tablet PC allowed us to see what users were doing during the test, and to give users a feel for stylus-based interaction with the screen. However, the form factor of the T3 handheld unit is considerably smaller, which might affect users' performance and acceptance. During the opportunity for informal feedback on the T3, none of the nurses indicated they thought it was too small to use. Despite this, testing the DSS in situ on the T3 would be advisable, to discover if any interface elements are hindered by the reduction in screen size.

Finally, a computerized decision support system can only be successful if it is actually used. There will need to be a certain degree of motivation on the part of the NCs to try something new, as well as encouragement and support from the developers and researchers involved. Feedback from the NCs should be closely monitored during the implementation stages of the final DSS. Acceptance testing after the system is in place would provide helpful information for future iterations, as well as valuable insight for future nursing decision support systems. Ideally, this would incorporate longitudinal testing of participants on the DSS over a period of several weeks, rather than in a single session, to give a better impression of how performance would be affected by the DSS over time. Because the DSS will eventually be used by less experienced nurses, and because the tested group of participants did not improve their quality of recommendations with the DSS even though it helped their assessment, it is advisable that these nurses receive training not only on the DSS, but also on teletriage in general before they are expected to take on a teletriage role.

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Appendix A

Telepractice Documentation Record

UNIVERSITY OF OTTAWA HEART INSTITUTE
INSTITUT DE CARDIOLOGIE DE L'UNIVERSITÉ D'OTTAWA

TELEPRACTICE DOCUMENTATION RECORD

☐Client ☐Family/Friend initiated ☐Nurse/Allied Health initiated	Spoke with: ☐Client ☐Family/Friend ☐Other ☐RN
Mode of Communication ☐Phone ☐Fax ☐Email	Name of OHI Cardiologist or Surgeon

Date	Time	NCC / RN / Allied Health (Circle Appropriate) First Name
Caller Name	Caller Telephone	Relationship to Client
Client Name	Client Telephone	Client DOB (ymd) / Client Gender ☐Male ☐Female

History at OHI

☐Cath ☐PCI ☐UA Date last hospitalization________	☐CHF ☐MI ☐Arrhythmia	☐CABG ☐Pre-op Date of OR__________ ☐Post-op Date of D/C__________	☐Valve ☐Aortic ☐Mitral ☐Transplant ☐Other	☐NO PREVIOUS HISTORY ☐Primary Prevention ☐Cardiac Rehab

Presenting Problem

☐Medication ☐Changing S & S ☐Complication	☐Pain ☐Fatigue ☐Information Needs	☐Sleep Problems ☐SOB ☐Appetite	☐Constipation ☐Anxiety ☐Coping Problems	☐ Other

Assessment

Advice / Counseling

Disposition of Call	Follow-up Summary	
Referral to: ☐ER ☐Family Physician ☐ See at OHI	☐Resolved	☐Informed OHI Physician
Patient agrees with plan of care ☐Yes ☐No	☐Call Back Arranged	
Signature/Status		

2003/03/13

Appendix B

Example of an NC Call Scenario (First Page)

D-blue

Call Scenario Template **Subj 2**

Patient complaint/concern:
55-yr-old female with unstable angina requiring repeated stents to RCA x 2, LAD x 2, Cx x 1 – also known to have 60% LAD lesion not stented. Most recent stent last week. Discharged home to <city in Northern Ont>. Called to discuss 2 episodes of chest pain since leaving hospital. Wants to know what to do.

You say
Hello - <name>, nursing coordinator speaking.

They say
My name is <name> and I had a stent put in last Tuesday – was discharged Wed to Intern's Residence then flew home Thursday. Friday I had angina again and I can't believe this.

You say
Mrs <name>, could you describe for me exactly the sensation that you had?

They say
Well, it seems to me to be the same pain. It started when I began to go through the week of mail that had accumulated. When I stopped doing that, it seemed to go away and I did try Nitro.

You say
How long did the episode last?

They say
Less than 10 minutes – about 5 minutes I think.

You say
It lasted 5 minutes and was relieved totally with the Nitro?

They say
Yes – Nitro fixed it but it happened again the next day.

You say
The 2nd episode occurred with activity also?

They say
Yes – similar activity and now I'm afraid to do anything.

You say
What have you been doing since you got home?

They say
Not very much.

You say
Have you been able to get up and around and do things for yourself?

They say
Yes, I have.

Appendix C

Interview Protocol

1. I noticed on the Telepractice Documentation Record, there are a number of fields to fill in such as caller vs. patient names, name of their surgeon or cardiologist, date last hospitalized, etc. I also noticed that this information was not included in any of the submitted scenarios.
    a. Do these fields normally get filled in?
    b. How do you get this information (i.e. start phone call by asking caller needed info, or by looking it up on a database afterward?)
    c. Are these forms sometimes incomplete when submitted?
        i. Why?
        ii. What fields are the ones that tend to be missing or incomplete?
    d. Do you find the telepractice form easy to use?
    e. Anything you particularly like or dislike?

2. During phone calls with patients, are you ever interrupted or disturbed by something outside the phone call?
    a. By what?
    b. How frequently?

3. Do you generally stand or sit during a phone call with a patient?

4. How do you go about training new NCs?

5. How long does it take for a new NC to get up to speed?

6. About the hardware:
    a. Have you used a handheld computer/PDA before?
    b. Have you ever used a Tablet PC before?

7. Is there anything else you feel we should know about the current system that would help us in developing the new system?

Appendix D

Interview Responses

Preliminary Questions
N=8

1. I noticed on the Current (paper) Telepractice Documentation Record, there are a number of fields to fill in such as caller vs. patient names, name of their surgeon or cardiologist, date last hospitalized, etc.

    a. Do these fields normally get filled in? Y N

- Yes: xxxxx
- No: xxx

    b. How do you get this information (i.e. start phone call by asking caller needed info, or by looking it up on a database afterward?)

- By asking the caller (x2)
- Ask caller
    - Patient's name
    - Type of (?)
    - Date of (?)
    - Usually can figure if male or female
- At start of call. (x2)
- Get info during call
- Clerk in CRFC will get the patient's name, procedure and doctor. Sometimes will confirm name, doctor, etc. If profile available, will look up info on patient.
- Bunker clerk gives basic info to start and get more detail from caller.

    c. Are these forms sometimes incomplete when submitted? Y N

- Yes: xxxxxxx
- No: x

If not,

i. Why not?

- If the patient had to go to an ER or the call sounded urgent, some areas may not get filled in.
- The caller giving the reason for the call; don't always backtrack for more detail.
- May not have the date of birth, phone #, or unique (?) – otherwise the rest is filled in

- Omission
- Time restricted

ii. What fields are the ones that tend to be missing or incomplete?

- DOB (x5)
- Telephone number (x4)
  - Including one "...if caller is waiting on the line"
- Presenting problem is usually written in under assessment (x2)
  - Including one "...but failed to tick"
- Caller name (x3)
  - Including "...if patient not calling" (x2)
- Relationship to client
- Unique (?)
- History at OHI
- Date of discharge

d. Do you find the telepractice form easy to use? Y N

- Yes: xxxxxxx
- No: [none]
- Did not answer: x

e. Anything you particularly like or dislike?

Like:
- Top section where all you have to do is tick the diagnosis
- Separation of patient symptoms and advice
- Bottom section of Follow Up

Dislike:
- Too much to fill in
- Bottom of page needing different options for referral
- Section on No Previous Hx, Primary Prevailing, Cardiac Rehab.
- History is usually written in (e.g. PCI last Feb ? date).
- Sometimes don't fill in difference between caller and actual patient because have to enter twice
- Order of patient name vs. caller – seems unnecessary for most calls
- Eliminate first line, client/family/nurse, because you ID them on the "Caller Name"
- DOB (like or dislike?)
- Fax and email likely used by triage (like or dislike?)

2. During phone calls with patients, are you ever interrupted or disturbed by something outside the phone call? Y N

- Yes: xxxxxxx
- No: x (if she can't take the call, she waits until she has time and calls the patient back)

   a. By what?

- Codes (x4)
  - Including "Code STEMI" (x2)
- Pages (x4)
- Family members trying to talk at same time as caller (x2)
- Beeper
- Urgent overhead paging
- Stat calls

   b. How frequently?

- Often (x4)
  - Includes one "very" and one "almost every call"
- Another family member on the line lots of times
- Not often
- Codes etc. just occasionally
- Have never actually had one (code) interrupt a call
- Depends on shift worked – if working alone: frequently, as level of responsibility goes up – on weekends: frequently, as busy ++

   c. What's the hardest part about returning to the task?

- If there is no time delay, usually I can resume the call. Usually I assess the problem and end the call quickly.
- Usually finish the call first
- Re-focusing on the problem.
- Keep caller focus!
- If you do not do it right away, remembering details is difficult. Must doc. directly on the sheet
- Just call patient back when emergency over
- Sometimes staying or managing yourself from being overwhelmed

3. Do you generally stand or sit during a phone call with a patient? Stand ____ Sit ____

- Sit: xxxxxxxx
- Stand: [none]
- Both actually, but I try to sit.
- Depends on where call comes in to (i.e. cell: stand, floor: stand, coffee shop: stand, office: sit)

4. How do you go about training new NCs?

- By showing what I would do on my shift and mentioning **possible scenarios.**
- Outline routine of the shift, specific commitments (i.e. classes, rounds). Role of the NC (i.e. triage, telehealth, education, crisis management for families, support for RN's.
- Normally show them the form. Usually assess right away how urgent the call is. Find out how they're feeling now. If it's a medication issue, can't change patient's issue. If it's new information (e.g. about medications) get them to repeat to make sure they understand it. Which is the hospital nearest you. Make sure the patient does not drive themselves to ER. If in pain after 3 Nitros, go to emergency.
- Do not review calls.
- (?) hands, provide **situations/scenarios.** Ensure they are comfortable with basic issues with patients, family, and crisis management.
- She spends 2 days with each day NC – 1 shift with card NC on E (?), (?) NC on E (?), and night NC. I think ½ day with triage and ½ day with trans(?) NC.
- For calls. Review telepractice document. Listen to # of calls being answered. Discuss problem post call and discuss intervention and (?). Monitor new NC responding to calls.

5. How long does it take for a new NC to get up to speed?

- Depends on previous experience.
- If they have worked in other areas and are familiar with general practice, 2 weeks
- 1-2 weeks of (?)
- It depends – probably a couple of months
- Several months or longer if new to HI.
- 6 months

6. About the hardware:

   a. Have you used a handheld computer/PDA before? Y N

- Yes: x
- No: xxxxxxx

   b. Have you ever used a Tablet PC before? Y N

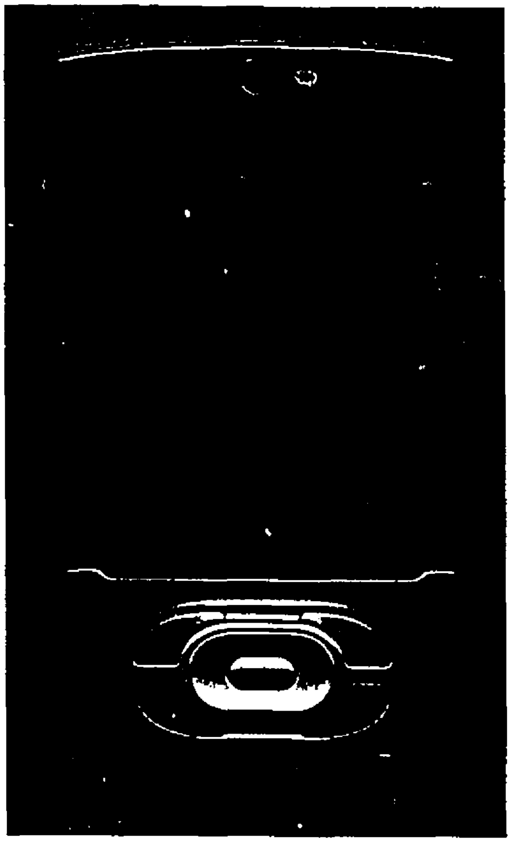
- Yes: x
- No: xxxxxxx

7. Is there anything else you feel we should know about the current system that would help us in developing the new system?

- One participant:
  - Don't know how many of these calls will be useful to have an algorithm
  - DVT – Positive Holman's sign
  - Med adjustment – get a hold of the doctor
  - EP
  - Post-PCI
  - Bowel bleeds, black stools
  - Nitro spray can be bought without a prescription
- Another participant:
  - Very few of the complaints are straight forward, e.g. a wife called to say her husband wasn't "picking up" – that he may have a cold, etc. – finally it was a dry cough that was the issue. Will we be able to deal with the round about issues?
- One more participant:
  - Perhaps to have the profile done on the computer – many calls come from recent discharges and much of data could be loaded on PDA during profile (?)
- Others had no comment

Appendix E

The Hardware: Palm Tungsten T3



Appendix F

Requirements and Constraints Summary

General system

- Easy enough for rank beginner PDA users
- Automatically save call at each step, so that if there is an interruption or inadvertent power-off, user can recover the call
- Enable retrieval of previous phone calls for records

Interaction

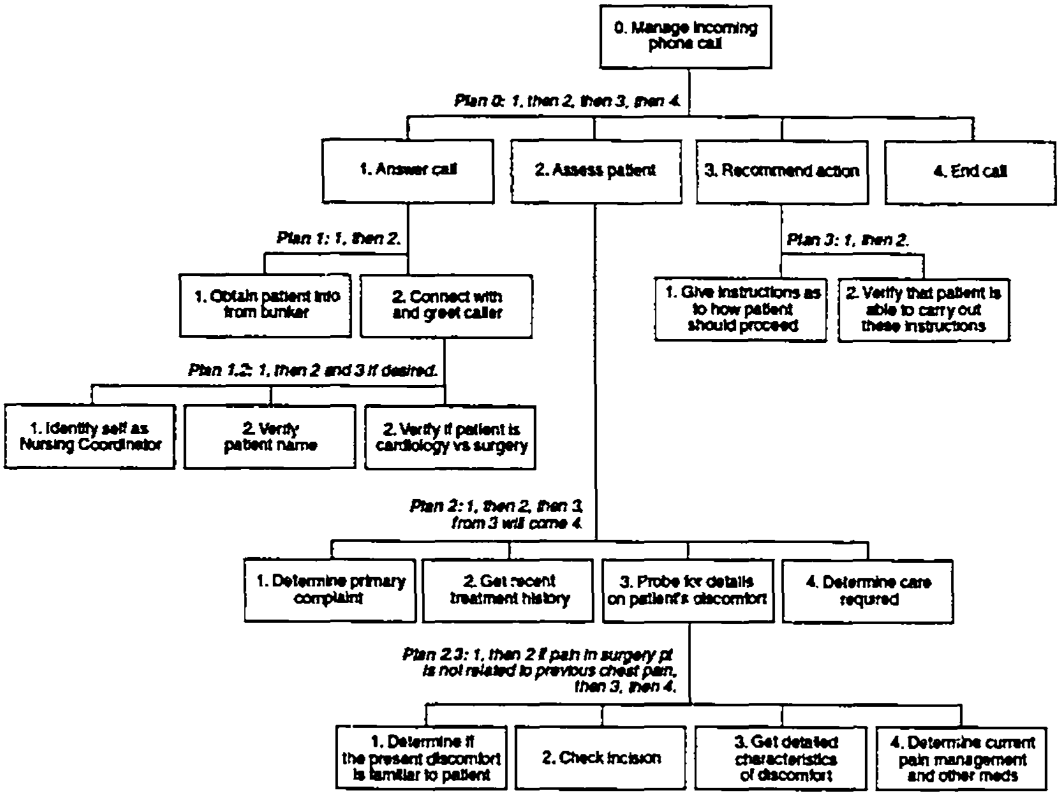
- Stylus interaction
- Support keyboard feature on T3 for input (users may not want to learn Graffiti)
- Use pick lists, checkbox lists, as much as possible to minimize need for typing/writing
- Avoid scrolling within screens – user may view interface on horizontal or vertical orientation

Interface

- Recall previous patient calls or start a new one
- Easily recall patient name during call
- Easily recall summary of details during call
- Must throw a flag as soon as it is evident the patient is in acute distress and requires immediate intervention
- Make it obvious to user that they can create a voice recording associated with the call
- May use colour in the interface (supported on the T3)
- Support general complaints "I'm not feeling well"
- Give additional support for less experienced nurses by having easily-accessible descriptions of what they should be looking for (i.e. how to tell if an incision is healing well)
- Support more experienced NCs by providing shortcuts to save time

Appendix G

Hierarchical Task Analysis Diagram



Appendix H

Workflow Chart

Preliminary Screen

- Button: "Call List"
- Button: "New Call" (biggest button, centered)
- Clicking "New Call" makes the following appear
    - Patient name
        - Not optional… user must enter a patient name before proceeding
        - "Next" button becomes available once user starts typing/writing name
    - Physician name (optional)
- User clicks "Next", go to Chart A

General

- Patient name appears at bottom left of main screen so user can refer to the caller by name during conversation
- Button at bottom right of main screen will bring up summary of call details at any point in the call
- "Back" button appears everywhere except on preliminary screen, so user can go back and make changes
- Availability of "Next" button will depend on whether user has entered enough information to go on to next step

Chart A

Step	Text	Options	Additional information
1. Primary complaint	Primary complaint:	Check box list: - ***Chest pain (go to 2)*** - Shortness of breath - Weakness - Question about meds - Generally unwell (go to 2)	If user checks "Generally unwell" and neither "chest pain" nor "SOB" are selected, pop up following message: "Probe for chest pain and shortness of breath before proceeding. [OK]" "Next" button appears once an item has been checked.
2. Recent treatment history	What did your doctor do for you when you were here? Did you	Drop-down pick lists: Cardiology: - Stents put in	

	have a procedure done?	(Go to chart B, step 1) - Angiogram (Go to chart B, step 1) - Other (Go to chart B, step 1) Surgery: - ***Bypass surgery (go to step 3)*** - Valve surgery - Other	
	When?	Drop-down pick list: - Yesterday - 2-3 days ago - 4-6 days ago - 1 week ago - ***2 weeks ago*** - 3 weeks ago - 1 month ago - 2 months ago - >2 months ago	"Next" button becomes available after user selects a procedure and time.
3. Is the discomfort familiar to patient (surgery), check incision	Is your discomfort like your pre-op angina or MI pain?	Drop-down pick list: - Yes - ***No*** - Don't know	
	Incision healing well?	Drop-down pick list: - ***Yes (go to step 4)*** - No	"More Info" button next to incision drop-down. On click, following text pops up: "Incision is healing well if: - No inflammation, swelling, redness - Drainage is clear or light yellow with no odour - Pt should not

			have drainage for any longer than 2 weeks post-op - [Close]
4. Probe for details of discomfort, and associated symptoms (OLDCART)	Describe your discomfort:	Drop-down checklists: How would you describe your discomfort? - Dull - Sharp - Aching - Pressure - Burning - Constant - Intermittent - ***Increases with deep inspiration*** - Like previous MI pain - Not like previous MI pain - Like previous angina pain - Not like previous angina pain When did it start? - Within the last hour - Today - Yesterday - ***Other*** Where is it? - ***Chest*** - Chest radiating down left arm - Arm - ***Shoulders*** - Neck - Face	"Next" button becomes available after user selects at least one item per list.

		- Jaw - ***Back*** - Head - Lower abdomen - Leg pain	
		Size? - ***Larger than the size of their hand*** - Larger than the size of their fist - Localized – can point to it with a single finger or no larger than a 50 cent piece On a scale from 0-10, with 0 being no pain and 10 being the worst pain you've ever felt, how would you rate this pain? "Calendar" selection row, with boxes containing numbers from 0-10. User clicks the box they want. [***2 or 3 for this case***] Duration? - ***Constant*** - < 1 minute - < 15 minutes - > 15 minutes - > 6 hours - Length of each episode has been increasing - Frequency of episodes has been increasing	"Next" button becomes available after user selects at least one item per list.
		Associated Symptoms: - ***None***	"Next" button becomes available

		- Sweating - SOB - Nausea - Vomiting - Weakness - Pallor - Palpitations - Fever - Runny nose - Sore throat - Cough Aggravating factors: - Hurts more when they press on it - ***Taking a deep breath*** - Movement of a body part - Mild exercise/activity - Vigorous exercise - Lying flat Relieving factors: - ***Nothing helps*** - Rest - Nitro - Sitting up - Sitting forward (ask patient to sit forward and take a deep breath) - Lying propped with 1 pillow - Lying propped with 2 pillows - Lying propped with 3 pillows	after user selects at least one item per list.
5. Check for unstable sternum	Do you have any clicking in your sternum, especially	Drop-down pick list: - Yes - ***No (go to PPS)***	"Next" button becomes available after user chooses

	when you're moving?		yes or no.
PPS	Possible PPS, (Post Pericardiotomy Syndrome) - Affects abut 10% of our post-op patients - Usually relieved by Ibuprofen - Some surgeons here don't like their pts to take Ibuprofen, so NC will check with Dr & get back to them - Get pt's phone number	Text field for user to input patient's phone number Number pad so user can tap numbers to add them, rather than writing them in Button: "Patient info" → goes to screen where NC can enter DOB, phone number (automatically entered from direct field in this case), other supplementary information Button: "Finished" → ends session, adds call to call list, goes back to decision support tool home page	

Appendix I

Cognitive Walkthrough: Questions to Keep in Mind

A. Will the users be trying to produce whatever effect the action has?

Are the assumptions about what task the action is supporting correct given the user's experience and knowledge up to this point in the interaction?

B. Will users be able to notice that the correct action is available?

Will users see the button or menu item, for example, that is how the next action is actually achieved by the system? This is not asking whether they will know that the button is the one they want. This is merely asking whether it is visible to them at the time when they will need to invoke it. An example of when this question gets a negative supporting story might be if a VCR remote control has a hidden panel of buttons that are not obvious to a new user.

C. Once users find the correct action at the interface, will they know that it is the right one for the effect they are trying to produce?

This complements the previous question. It is one thing for a button or menu item to be visible, but will the user's know that it is the one they are looking for to complete their task?

D. After the action is taken, will users understand the feedback they get?

Assuming the users did the correct action, will they know that. This is the completion of the execution/evaluation interaction cycle. In order to determine if they have accomplished their goal, the user needs appropriate feedback.

Adapted from:

Alan Dix, Janet Finlay, Gregory Abowd and Russell Beale, *Human-Computer Interaction*, Prentice Hall, International, 1993. Chapter 11 contains information on evaluation techniques.

Clayton Lewis and John Rieman, *Task-Centered User Interface Design: A practical introduction.* A shareware book published by the authors, 1993. Original files for the book are available by FTP from ftp.cs.colorado.edu.

Cathleen Wharton, John Rieman, Clayton Lewis and Peter Polson, *The Cognitive Walkthrough: A practitioner's guide.* In Jakob Nielsen and Robert L. Mack, editors, *Usability Inspection Methods.* John Wiley and Sons, Inc. 1994.

Source:

http://www.cc.gatech.edu/computing/classes/cs3302/documents/cog.walk.html

Appendix K

OLDCAR Pain Characteristics

PDA Decision Support OLDCAR Assessment Tool

Onset
Within the last hour
Today
Yesterday
Other

Location
Chest
Chest radiating down left arm
Arm
Shoulders
Neck
Face
Jaw
Back
Head
Lower abdomen
Leg pain

Duration
Constant
< 1 minute
< 15 minutes
> 15 minutes
> 6 hours
Length of each episode has been increasing
Frequency of episodes has been increasing

Characteristics
Type
Dull
Sharp
Aching
Pressure
Burning
Constant
Intermittent
Increases with deep inspiration
Like previous MI pain
Not like previous MI pain
Like previous angina pain
Not like previous angina pain
Same pain as during their angioplasty balloon inflation
Not same pain as during their angioplasty balloon inflation
Size
Larger than the size of their hand
Larger than the size of their fist
Localized – can point to it with a single finger or no larger than a 50 cent piece
Severity - Pain scale (0 – 10)

Associated Symptoms
Sweating
SOB
Nausea
Vomiting
Weakness
Pallor
Palpitations
Fever
Runny nose
Sore throat
Cough

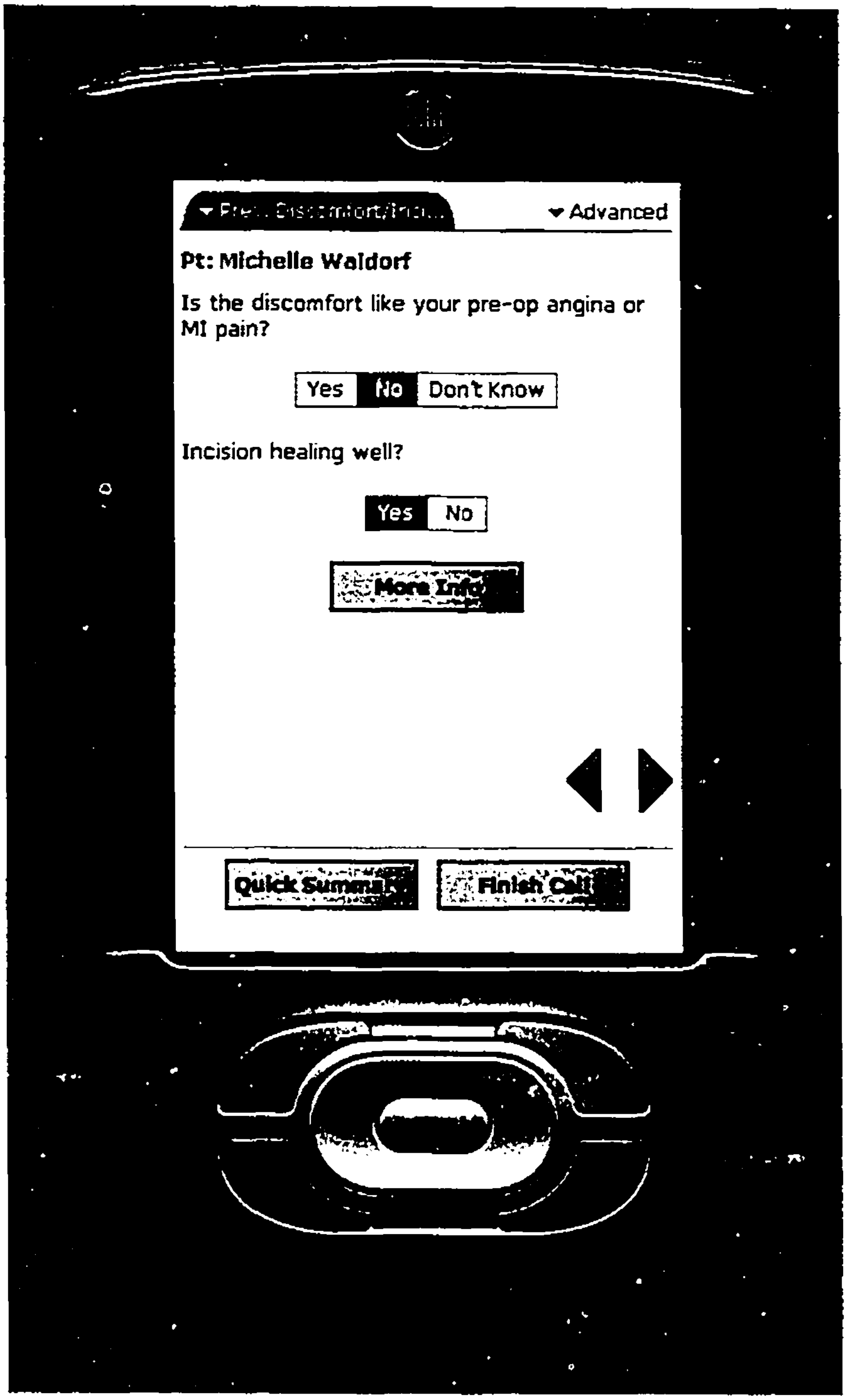
Aggravating Factors
Hurts more when they press on it
Taking a deep breath
Movement of a body part
Mild exercise / activity
Vigorous exercise
Lying flat

Relieving Factors
Nothing helps
Rest
Nitro
Sitting up
Sitting forward
Lying propped with 1 pillow
Lying propped with 2 pillows
Lying propped with 3 pillows

Version 1.0
May 1, 2005

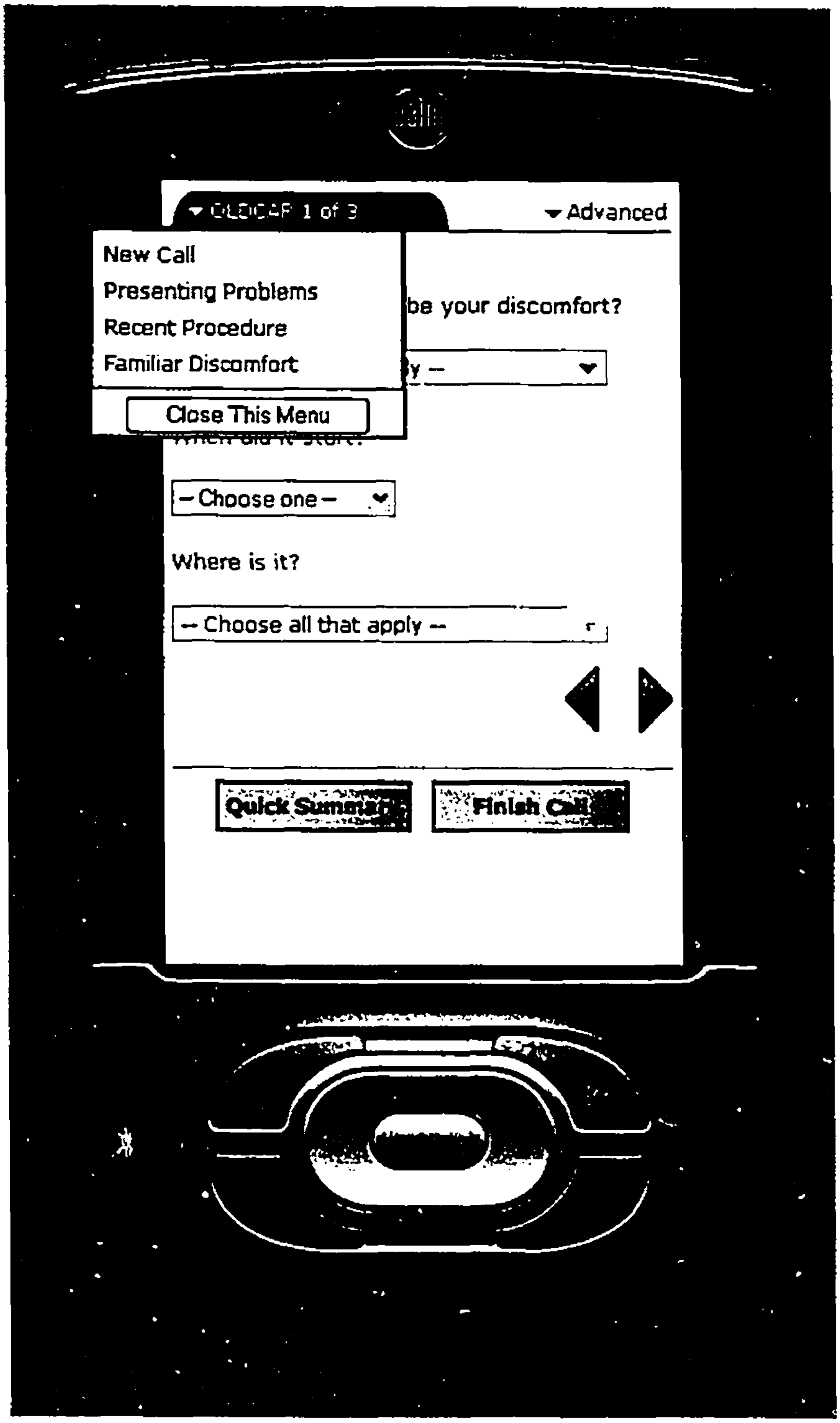
Appendix L

Mid-Fidelity Prototype – Sample Screen Shot



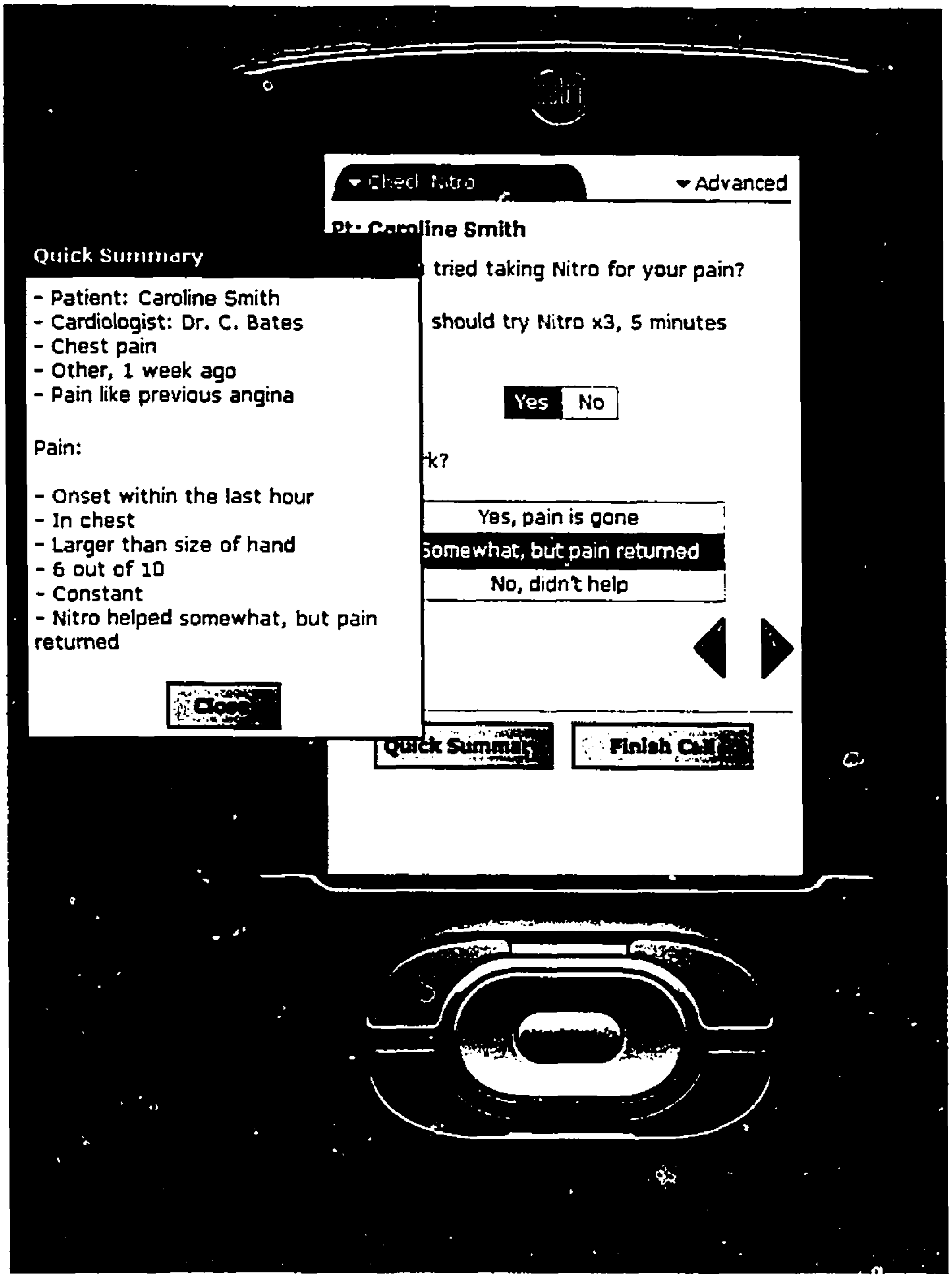
Appendix M

Mid-Fidelity Prototype – Breadcrumb Menu



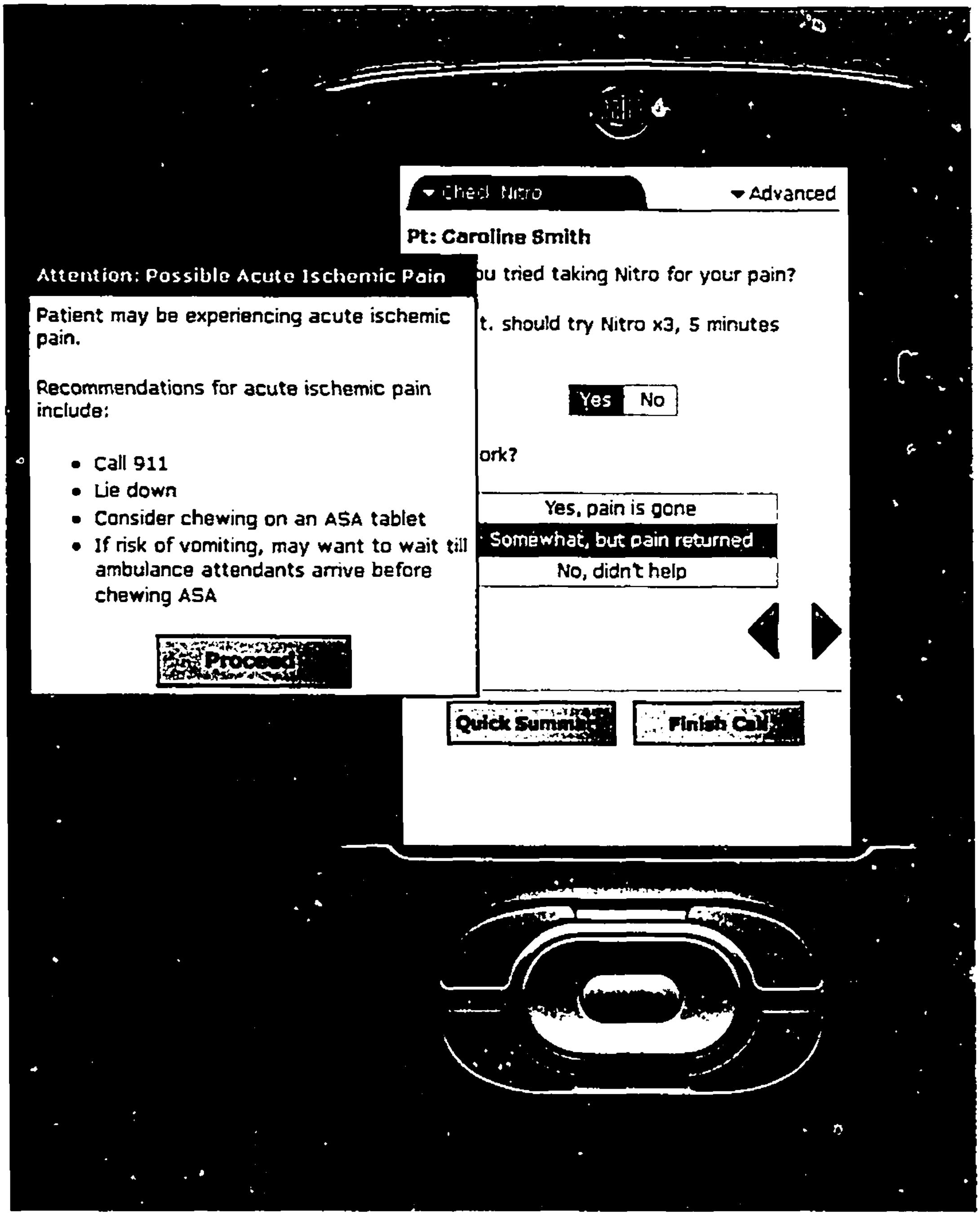
Appendix N

Mid-Fidelity Prototype – Quick Summary



Appendix O

Mid-Fidelity Prototype – Flag (Automated DSS Assessment)



Appendix P

Recruitment Poster

Nurses, We Need You!

PDA Decision Support Tool Study

****** 1 day free parking ******

Dear Colleagues,

We are currently conducting a study of telehealth in collaboration with Carleton University. This study aims at better understanding of how healthcare providers answer questions asked by patients who call in after treatment in hospital. These results shall be used to make recommendations toward the design of a computer-based decision support tool for nurses. We are seeking volunteers to participate in this study. You will have direct input into the design of the new decision support tool, and we will follow up to let you know the outcome of the study if you are interested. There are no known risks to participating in this study. To participate, you must currently be employed as a cardiac nurse at the Heart Institute and be able to participate in two sessions of 1 hour to 1.5 hours long. The data collected from your participation in this research study will be maintained in the strictest confidence according to the guidelines established by the Carleton University Ethics Committee for Psychological Research. If you are interested in participating or have further questions please contact me via phone or email as per details below.

Warmest regards,

Kathryn Momtahan RN, PhD
Nurse Scientist, University of Ottawa Heart Institute
kmomtahan@ottawaheart.ca
x 13575

DST Study kmomtahan@ottawaheart.ca 798-5555 ext. 13575	DST Study kmomtahan@ottawaheart.ca 798-5555 ext. 13575	DST Study kmomtahan@ottawaheart.ca 798-5555 ext. 13575	DST Study kmomtahan@ottawaheart.ca 798-5555 ext. 13575

Appendix Q

Informed Consent Form

UNIVERSITY OF OTTAWA HEART INSTITUTE / INSTITUT DE CARDIOLOGIE DE L'UNIVERSITÉ D'OTTAWA
40 rue Ruskin Street, Ottawa, Ontario K1Y 4W7 www.ottawaheart.ca

INFORMATION SHEET AND CONSENT
for
INTERVIEW PARTICIPANTS
UOHI-05-150, ORE #11940

Handheld Medical Decision Support Tools: Designing an Effective Interface

Principal Investigators: Dr. Kathryn Momtahan, RN, PhD (613) 798-5555, ext.13575
Dr. Gitte Lindgaard, RN, PhD (613) 520-2600, ext. 2255

Co-Investigators: Kirsten Carroll Somoza, BS (613) 234-0750

Study Coordinator: Dr. Kathryn Momtahan, RN, PhD (613) 798-5555, ext.13575

Please read this Information Sheet and Consent Form carefully and ask as many questions as you like before deciding whether to participate.

INTRODUCTION

We are conducting a study to develop and test patient care algorithms on personal digital assistants (PDAs) to support telephone consultations to cardiac patients, using best practices. The goal of the project is to develop a tool that can support primary care healthcare practitioners such as family physicians and nurses working in family medicine clinics when they receive calls from cardiac patients. The study will run from November, 2004 to the end of March 2006, a period of 17 months. Your participation will involve two interview sessions, the first one will last approximately one hour and the second one, to be conducted within a few weeks of the first one, will last approximately 1.5 hours. The purpose of the first interview is to help us see how nurses currently handle patient calls. The second interview will help us find usability problems in a prototype of a PDA tool before the nursing coordinators at the University of Ottawa Heart Institute test the tool on live calls with patients.

PROCEDURE

During the baseline interview, you will be asked to proceed through four mock phone calls with someone who will play the role of a patient. During these calls, you will use whatever reference material and other tools you normally have at hand during a patient call. During the prototype interview (the second interview), which will be scheduled at a later date, you will be asked to complete a short exercise on a Tablet PC to learn how to interact with it. You will then use a prototyped tool to guide you through four mock phone calls. We will ask you to rate the prototype, and give us your comments. Finally, you will handle a T3 Personal Digital Assistant and give us your feedback on it. The first session will last approximately one hour, and the second session will last approximately 1.5 hours.

RISKS and DISCOMFORTS of PARTICIPATION

There are no anticipated risks or discomforts involved in this study.

BENEFITS OF PARTICIPATION

Although there may be no direct benefits of this study to you, it is hoped that the end result will be that the usability of the prototype software for use by the nursing coordinators will be improved.

COMPENSATION/RENUMERATION

There is no personal monetary compensation to being in the study. Parking fees will be reimbursed.

CONFIDENTIALITY

All records will be kept confidential. Any documentation and interviews will be reviewed by the investigators, both at the University of Ottawa Heart Institute, at the University of Waterloo, and at Carleton University, and may be reviewed by representatives from the Ontario Ministry of Health, or representatives of the Research Ethics Boards at the University of Ottawa Heart Institute and at the University of Waterloo under the supervision of the investigators or their staff. You will not be identified in any publications by name or initials. All data sheets will have your number only on them and they will be kept in a locked office at the Heart Institute. Data will be stored for a period of 8 years. A video camera will be used during the sessions to record hand-level interaction with the prototype, and with other resources you use to proceed through the scenarios. The camera will not be focused on your face. You may opt out of the recording procedure if it makes you uncomfortable. All videotapes will be destroyed once the data analysis has been completed.

ETHICS

This study has been approved by the Human Research Ethics Board of the University of Ottawa Heart Institute, and has been reviewed and cleared through the University of Waterloo Office of Research Ethics and the Carleton University Research Ethics Committee for Psychological Research. These institutional ethics review structures consider the ethical aspects of all research projects using human subjects being conducted by researchers in their institutions. If you wish, you may talk to the Chair of the Human Research Ethics Board at the University of Ottawa Heart Institute through the Secretariat at (613) 761-4417 or contact the University of Waterloo Office of Research Ethics at (519) 888-4567, ext. 7163. You may also contact the Chair of the Carleton University Research Ethics Committee for Psychological Research at (613) 520-2600, ext. 2664, or the Chair of the Carleton Department of Psychology at (613) 520-2600 ext. 2648.

VOLUNTARY PARTICIPATION **Participation in research is completely voluntary.**

You are free to choose whether to participate in this study or not. If you choose to participate, you may choose to withdraw your consent at any time. If you are a Heart Institute employee, this will not affect your employment at the Heart Institute in any way. You are also free to refuse to answer any questions that you may be asked because of your participation in this study.

CONSENT TO PARTICIPATE IN RESEARCH

I understand that I am being asked to participate in a research study on using personal digital assistants and patient care algorithms to improve access to cardiac care best practices. By giving my consent, I am authorizing the University of Ottawa Heart Institute to review my data for the purposes of this study. I am also agreeing to be interviewed for the purposes of this study.

I have read and understood this Information Sheet and Consent Form. All of my questions at this time have been answered to my satisfaction. If I have any further questions about this study, I may contact the Principal Investigator Dr. Kathryn Momtahan at (613) 798-5555, x 13575.

I will receive a signed copy of this Consent Form and the attached Information Sheet.

I voluntarily agree to participate in this study.

Name________________________________

Signature________________________________

Date____________________

Signature of person obtaining Consent________________________

Investigator / Co-Investigator's Signature________________________

I voluntarily agree to be videotaped as part of this study.

☐ Yes ☐ No

Appendix R

Baseline Interview – Pre-Interview Questionnaire

Participant #:

1. How many years have you worked with **cardiac surgery** patients? ☐
2. How many years have you worked with **cardiology** patients? ☐
3. How many years have you worked in **cardiac nursing**? ☐
4. How many years have you worked in **nursing, in general**? ☐
5. Do you have any experience managing calls from cardiac patients?

   Yes ☐ No ☐

   If Yes, please describe briefly:

   ☐

6. Your age is:

   ☐ 18-25

   ☐ 26-35

   ☐ 36-45

   ☐ 46-55

   ☐ 56-65

   ☐ 66+

Appendix S

Baseline Test Script

Thank you for helping us in our study. During this interview, we will ask you to participate in some patient phone call scenarios. There will be four different scenarios, based on different types of pain complaints, where the patient is calling seeking advice. These calls are hypothetical calls from Heart Institute patients who have been discharged home, or who have been seen in clinic. You are playing the role of the Nursing Coordinator. Your objective is firstly to assess the patient's complaint, and secondly to recommend action. In each scenario, the bunker is providing you with the patient's name and the name of their Heart Institute physician.

Are you ready to begin?

Appendix T

DSS Test Script

a) Introduction

Thank you for helping us to test our decision support system interface. This session will be in three parts, and will take about 1 hour. During the first part, you will have an opportunity to familiarize yourself with the Tablet PC. During the second part, you will test a decision support system prototype, and fill out a questionnaire. During the final part, you will evaluate the Palm T3 PDA, which has been chosen to deliver the finished decision support system. Are you ready to start?

b) Interaction Exercise

During this session you will be using a Tablet PC. I want to make sure you are comfortable during this process. Are you right or left handed? [Position Tablet near dominant hand, with Interaction Exercise launched] The first thing I will ask you to do is to peruse a short tutorial to learn how to interact with it. When you feel comfortable, let me know and we will continue. [Wait until participant is done with tutorial]

c) Pain Scenarios

We will now start the test on the prototype. This is a prototype of a decision support tool, developed to help Nursing Coordinators assess and advise patients over the phone. In these hypothetical scenarios, the patient is calling in to the Heart Institute. There will be four scenarios, based on different types of pain complaints. For each one, the bunker will call you, at which point you will pick up the phone handset. The bunker will give you the patient's name and the name of the patient's Heart Institute physician. They will connect you with the patient when you tell them you're ready. At some point in the call, I will interrupt you to ask for your assessment of the patient's problem. You will then give the patient advice based on your assessment. When you have completed the call, hang up the phone. As much as possible, I would like you to try to work through any difficulties on your own, but if you get really stuck you can ask me for assistance. I will give you the opportunity to offer your feedback after each call is completed.

After you complete all four scenarios, I will ask you to fill out a questionnaire rating your experience with the tool on the whole. Remember that throughout this process, you are helping us test a design: we are NOT testing you as a user. Also remember that this is a simulation, and you are not speaking with real patients. Do you have any questions? [Satisfy any questions] Let me take a moment to launch the application. [Launch prototype on Tablet] Go ahead and click "New Call" to start a new call. You should know that if you type information into an "Other" field in the prototype, it will not be recorded – so you may consider writing it down on the pad if you want to refer back to it. Please speak up so the recorder can catch your comments. Are you ready? [Wait for affirmative] I'll let our bunker know we're ready to begin. [Call "bunker" to let them know we're ready... facilitator will do this after each scenario, to give evaluator time to fill in post-scenario questionnaire] *d) Evaluation of T3 Hardware*

The Heart Institute has selected this PDA as the one that will carry the decision support tool once it is developed. [Show the evaluator how to turn on the T3, slide the display open, and remove the stylus. Hand it to the evaluator in the closed position, with the stylus in situ] It works similarly to the Tablet, in that you can interact with it using a stylus. I would like you to try it out, while you have the telephone in your other hand. Feel free to explore any of the built-in features. Please think aloud as you go, noting any difficulties or things that you like. Take as long as you'd like. When you're finished, let me know. [At the end of session, if evaluator has not opened the sliding screen at all during their assessment of the hardware: "Is there a reason you didn't bother with the sliding screen?"]

Appendix U

Facilitator Worksheet

<table>
<tr><td>Evaluator number:</td><td colspan="3"></td></tr>
<tr><td>Scenario (A, B, C, or D):</td><td></td><td>Order (1, 2, 3, or 4):</td><td></td></tr>
<tr><td>Evaluator running comments, if any:</td><td colspan="3"></td></tr>
<tr><td rowspan="5">Facilitator intervention required:</td><td>Where?</td><td>Hint given</td><td>Recovered after intervention?</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Arrived at correct end-point in algorithm?</td><td colspan="3"></td></tr>
<tr><td>Other comments:</td><td colspan="3"></td></tr>
</table>

Appendix V

Post-Scenario Feedback Form

Participant: *Scenario:*

Post-Scenario Feedback Form

Please rate how comfortable you were using this system by placing a mark at any point along this line. The midpoint indicates neither uncomfortable nor comfortable.

Very Uncomfortable —————————|————————— Very Comfortable

Please give us any other comments you have about your experience navigating through this scenario.

Appendix W

Post-Test Questionnaire

Participant:

Post-Test Questionnaire

This questionnaire gives you an opportunity to tell us your reactions to the decision support system you used. Your responses will help us understand what aspects of the system you are particularly concerned about and the aspects that satisfy you. To as great a degree as possible, think about all the tasks that you have done with the system while you answer these questions. Please read each statement and indicate how strongly you agree or disagree with the statement by placing a mark on the line scale. The midpoint of the line indicates neither agreement nor disagreement. Please write comments to elaborate your answers. Thank you!

1. Overall, I am satisfied with how easy it is to use this system.

Strongly Disagree ———————————— Strongly Agree

Comments:

2. I could effectively complete the scenarios using this system.

Strongly Disagree ———————————— Strongly Agree

Comments:

3. I was able to efficiently complete the scenarios using this system.

Strongly Disagree ———————————— Strongly Agree

Comments:

4. It was easy to learn to use this system.

Strongly Disagree ——— Strongly Agree

Comments:

5. I believe I could become productive quickly using this system.

Strongly Disagree ——— Strongly Agree

Comments:

6. It was easy to find the information I needed.

Strongly Disagree ——— Strongly Agree

Comments:

7. The information was helpful to me in completing the scenarios.

Strongly Disagree ——————————————— Strongly Agree

Comments:

8. The organization of information on the screens was clear.

Strongly Disagree ——————————————— Strongly Agree

Comments:

9. The order of the screens made sense.

Strongly Disagree ——————————————— Strongly Agree

Comments:

10. This system has all the functions and capabilities I expected it to have.

Strongly Disagree ——————————————— Strongly Agree

Comments:

11. I felt comfortable using the stylus to interact with the screen.

Strongly Disagree ——————————|—————————— Strongly Agree

Comments:

12. I felt comfortable using the system while talking on the phone.

Strongly Disagree ——————————|—————————— Strongly Agree

Comments:

13. I felt (please check one)

- ☐ more
- ☐ equally
- ☐ less

confident in my assessment with this system than without it.

Comments:

14. I felt (please check one)

- ☐ more
- ☐ equally
- ☐ less

confident in my advice with this system than without it.

Comments:

15. Overall, I am satisfied with this system.

Strongly Disagree ——— Strongly Agree

Comments:

16. Please describe what you liked best about this system.

17. Please comment on parts of this system you feel could be improved.

Appendix X

Debriefing Form

Debriefing Form

Thank you for participating in this study. We know you are busy, and very much appreciate your time. The feedback you gave us today will help us develop the design of a handheld decision support tool for cardiac care nurses. The other Nursing Coordinators will also be participating in this study. Please do not discuss the study with those who have not yet participated, as it may influence their comments.

Research personnel:

The following people are involved in this research project and may be contacted at any time:

Kirsten Carroll Somoza (Principal Investigator, 520-2600 x6628)
Dr. Gitte Lindgaard (Faculty Sponsor, 520-2600 x2255)
Dr. Kathryn Momtahan (Co-supervisor, 798-5555 x13575)

Should you have any ethical or other concerns about this study then please contact: Dr. Chris Davis (Chair, Carleton University Research Ethics Committee for Psychological Research, 520-2600 x2664) or Dr. Mary Gick (Chair, Department of Psychology, 520-2600 x2648).

Appendix Y

Where Participants Strayed from the Screens

PPS – Where Participants Strayed from the Screens							
Screen\ Participant	1	2	3	4	5	6	7
New Call							
Pres Prob	Any other symptoms	Describe discomfort	Any other symptoms		Any other symptoms	Any other pain or discomfort	Tell me a little more
Recent Proc							
Prev Dis/Inc							
Old Car 1							
Old Car 2							
Old Car 3		Asks about Tyl.				Asks about pain meds	
Check Sternum							
Meds							

Ischemic Pain – Where Participants Strayed from the Screens							
Screen\ Participant	1	2	3	4	5	6	7
New Call							
Pres Prob				Be a bit more specific	Have you had this before		
Recent Proc							
Prev Dis		Skipped this					
Old Car 1							
Old Car 2		Skipped this					
Nitro		Jumped to 911			Jumped to 911		

Cardiac Tamponade – Where Participants Strayed from the Screens							
Screen\ Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**
New Call							
Pres Prob		What kind of chest pain	Does it go anywhere		Have you had this before	Have you had this before	
Recent Proc							
Prev Dis/Inc		Are you tired					
Old Car 1							
Old Car 2							
Old Car3			Asked about BP equip.				

Stent Pain – Where Participants Strayed from the Screens							
Screen\ Participant	1	2	3	4	5	6	7
New Call							
Pres Prob	How long have you had it			Describe pain	Is this new	When did it start	
Recent Proc		Pain increases		Skipped this			
Prev Dis							
Old Car 1							
Old Car 2							
Old Car 3							
Meds		Asks about pillows		Skipped this			