From Paper to PDA: Design and Evaluation of a Clinical Ward Instruction on a Mobile Device

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Abstract. Mobile devices with small screens and minimal facilities for interaction are increasingly being used in complex human activities for accessing and processing information, while the user is moving. This paper presents a case study of the design and evaluation of a mobile system, which involved transformation of complex text and tables to digital format on a PDA. The application domain was an emergency medical ward, and the user group was junior registrars. We designed a PDA-based system for accessing information, focusing on the ward instruction, implemented a prototype and evaluated it for usability and utility. The evaluation results indicate significant problems in the interaction with the system as well as the extent to which the system is useful for junior registrars in their daily work.

Keywords: Interaction design, mobile system, usability evaluation, interpretive evaluation, case study.

1 Introduction

Mobile devices with a range of purposeful applications have changed many jobs that involve working in new settings and on the move. The challenge for user interaction design is to create applications that are useful in the mobile situation despite severely reduced interaction facilities.

Many early applications on mobile devices involved user interaction with only simple data, e.g. communication facilities (mobile telephone, SMS), and games. This applies also to recent applications like music and video players and cameras. Yet other applications for mobile devices involve more complex data in long lists or large tables. Early examples include calendars, address books and web browsers. Today, applications like email, calendars, contact lists and finance systems as well as systems for sales, business, medicine, travel and education involve complex data in list or table structures. Recent systems for instruction, direction, training, visualization, localization, social networking, remote monitoring, and accessing and browsing information on the web also involve user interaction with very complex data.

Complexity of information is a key difficulty for such applications. This complexity originates either from the sheer amount of information or from the

intricate and dense nature of the information [24]. Complexity originating from the amount of information is particularly challenging for the design of systems for mobile devices. Handheld mobile devices have very limited facilities for user interaction; most notably the small size of the screen, but also the replacement of standard input devices like keyboard and mouse with compressed and minimized keyboards, a few control buttons and a stylus. A number of studies have examined the consequences of these differences [1, 8, 10, 29].

This paper contributes to research on interaction design and evaluation of complex information systems for mobile devices. We report from a case study of the design and evaluation of a clinical ward instruction on a mobile device for use in an emergency medical ward. The health care domain is interesting, both because there is increasing focus on the possibilities of deploying mobile systems for use by physicians and nurses [11, 28], and because it is so difficult to develop successful systems.

The paper is organized as follows: In the following section, we present existing research on complex information processing on mobile devices, including experiences from the healthcare domain. Next, our case is described with emphasis on the design challenge. Then we present the transformation of paper instructions into digital form for a PDA. This is followed by results from a conventional usability evaluation and a qualitative interview-based evaluation of utility. Experiences acquired through the study are discussed, and the conclusion sums up and suggests areas for future work.

2 Related Work

There are several studies of interaction with text and tables on mobile devices and the effect of physical movement on text reading and comprehension. Some of these have shown that in various use situations physical movement may reduce performance in the interaction with a mobile handheld device [4, 21, 23, 25, 27, 33]. This occurs for two reasons: (1) the user moves between different locations and thereby changes context of use [16,20]; and (2) the user moves physically which reduces the possibility for precise interaction [27]; this second reason has been examined in a number of studies, documenting that performance is reduced and task load increased when the user is mobile, e.g. [21, 23, 25, 26, 33].

The difficulties of interacting with complex information in tables on mobile devices have been examined in a number of studies, e.g. on table lookup on a small screen [34] and visualization of lists with patient data on a small screen [21]. However, the majority of these studies have been more design-oriented, e.g. [29, 35]. Surprisingly, none of these studies have inquired into the effects of physical movement on user performance.

A key challenge when complex information has to be presented on small screens is to find optimal levels of information hierarchies. Results from a comparison of mobile web browsing with desktop browsing indicate poor performance on a mobile browser, especially when trying to locate content in long narrow pages, because it requires extensive scrolling [29]. A solution to mobile browsing fatigue has been suggested [1]. Another study compared interfaces using zoom and overview with classic zoom

interfaces in the context of user navigation of large information spaces on mobile devices [5]. Similar results about overview were found in a study of the usability of four different information hierarchies on mobile devices [12]. These studies improve our understanding of the challenge faced when working with complex information for mobile devices, and they demonstrate that performance is reduced when using desktop designs and scroll interaction for the mobile device, whereas performance is increased when the design provides overview of the complex information.

Some studies have dealt specifically with the use of mobile devices in healthcare. A survey of 3600 users of a handheld clinical reference application reported that current adopters used these tools frequently and found them useful for improving patient care and learning [28]. Similarly, the affordance of handheld computers to clinical practice has been pointed out [1, 2]. However, a literature review on the use of handheld devices in medicine, emphasizes a lack of evidence-based information about the use of PDAs in medicine [11]. A review on adoption of PDAs in healthcare identifies major barriers to adoption, including usability problems, security concerns, and lack of technical and organizational support. Better designed PDA hardware and software applications, more institutional support, seamless integration of PDA technology with hospital information systems, and satisfactory security measures are necessary to increase acceptance and use [22]. Finally, a study identified ward instructions as a central and complex information need [8].

3 Case: A Ward Instruction in an Emergency Medical Ward

The case study reported in this paper was carried out at an emergency medical ward at a large regional hospital in Denmark. The ward that participated in the project is staffed with 16 junior registrars. Due to rotation, 20 registrars in total participated in the different activities of the project.

The target group of users was junior registrars, i.e. physicians who have just ended medical studies in university and face one year of clinical training including six month at a medical ward. Junior registrars need to operationalize their theoretical knowledge into clinical decision making in concrete situations [17, 18]. To support this acquisition, information, typically in paper format, is carried in the pockets of their white coats. Figure 1(a and b) shows an average white coat of a junior registrar at the ward with the average weight of 2,6 kilos. The pocket content is displayed in (b) with reference tables on medicine, phone numbers, diagnosis codes etc., ward instruction, personal notebooks, text books, keys, pens and medical equipment.

Inspired by the junior registrars' request for and recommendation of mobile technology to support their clinical training [14], a research project was carried out with the aim of identifying relevant mobile applications [18]. The project was organized as a participatory design process with initial observations, interviews and a workshop with physicians at the ward. These activities identified the clinical ward instruction as the most central, obligatory and used information material for junior registrars and clinical staff at the ward in general [17]. This focus was supported by related research on handheld devices to support junior registrars in Danish hospital training [8].

The clinical ward instruction is written by the chief physicians and includes descriptions of archetypes of diseases at the ward, list of symptoms, checklists, and instructions for monitoring and treatment. It represents high level expert knowledge, and the instructions are procedures that have been decided upon, and they must be followed by staff.

(a) (b) (c)

Fig. 1. (a) The white coat of a junior registrar. (b) The content of the white coat pockets (in total2.6 kg). (c) The clinical ward instruction made by chief physicians at the ward.

Figure 3(c) shows a ward instruction that has been used for four months by a junior registrar. It is size B5, and the text includes coherent text chunks up to 25 normal pages, in addition to a set of tables, each being typically the size of a full page. Personal notes are added in the margin with the purpose of keeping track, highlighting, and saving advice and experience.

The aim of digitizing the complex information of the ward instruction in a mobile device was complemented with observations of and interviews with junior registrars emphasizing the following meaning of mobility at the medical ward:

- Mobile means walking – the physicians walk while looking up information and interaction techniques for on-the-move-interaction like e.g. one hand interaction, were emphasized.
- Mobile means in-between, on the way from one task to the next. Maximum time for looking up information or making notes was defined to app. 5-10 minutes. As explained by one of the physicians: “if you have more than 10 minutes, you find a PC”. Consequently, navigation supporting easy to find was emphasized.
- Work is filled with interruptions. The physicians are constantly interrupted and as a consequence working hard to keep track via personal notebooks on their patient. Emphasis was on not designing yet another interrupting artifact but rather a personal device supporting tracking of work activities.

4 Interaction Design

The key decisions in the development of the prototype were the design of the basic form of interaction with the digital ward instruction and the transformation of the

paper ward instructions into the digital version. These decisions were made in a participatory process that involved the physicians at the ward.

The transformation of the paper version to the digital version on the PDA faced the following challenges: create a useful structure for a database, develop a software editor for producing elements within this structure and design the detailed interaction with the ward instruction on the mobile device.

It was decided to structure the digital ward instruction around archetypes. This decision was based on empirical analysis and a theoretical perspective on medical knowledge [13]. An archetype is a patient with a well-known disease, e.g. the febrile patient. The reasons for this fundamental decision were that archetypes are related to the use situation of the application, and archetypes support the transformation of theoretical knowledge to concrete decision making in clinic faced by the junior registrars: to fit a patient into a correct archetype and perform the necessary individual patient-specific adjustments compared to an abstract, average patient described in the archetype.

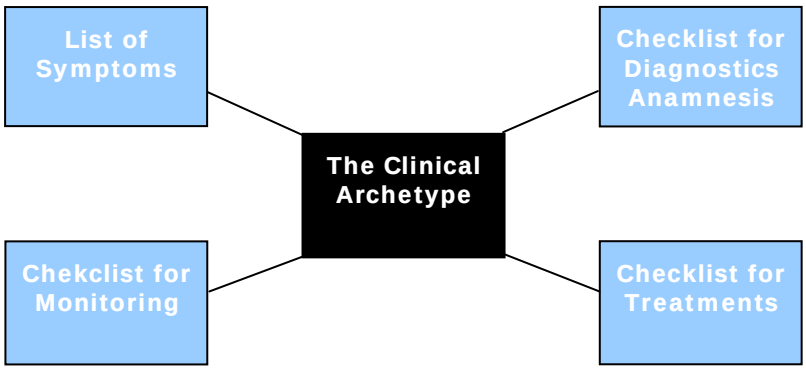

Fig. 2. The basic structure of the digital ward instruction.

The transformation of the existing paper archetypes into digital archetypes was carried out on the basis of a modified general work-flow model with the following four “milestones”, see Fig. 2:

- List of symptoms and signs that contains specific ideas for further and alternative information relevant for a more precise positioning of the patient within the range of the archetype diagnoses.
- Checklist for diagnostics, objective findings and test that contains relevant ideas for specific hospital procedures.
- Checklist for treatment that contains plans for treating the patient.
- Checklist for monitoring that also contains alternative actions.

The software used as editor for producing text on the digital archetypes was designed in Microsoft Word. This was reasonable since the text for the existing ward instructions on paper, see Fig. 1(c) was in Word, and because this software was known to the archetype-producers (the chief physicians). They were allowed to mark and prioritize the order in which they entered the text for later hyperlinking by means of a parser constructed in the project.

The transformation of the long texts for each archetype (some were up to 25 normal pages) has been done by designing the navigation for the text according to general design guidelines and empirical knowledge from the case. Focus was on:

- Interaction using both screen and buttons
- A frontpage with shortcuts to key functions
- Direct access through search functions
- Providing overview of the main information

Interaction design was not only based on the small screen of the PDA but also on the hardware as interface. A shortcut to the ward instruction was programmed and works with activation of a button at the front of the PDA.

(a) (b) (c)

Fig. 3. Screen-dumps from the digital ward instruction. (a) The frontpage with key functions. (b) Search functions. (c) An example of an archetype organized in headlines.

There were shortcuts to key functions in the digital ward instruction via a frontpage that gives access to (1) instructions organized in archetypes, (2) personal notes, (3) tables with specific information and (4) a link to a national website with medical handbooks, drug catalogues etc. Usually, the junior registrars are carrying heavy books with the information mentioned in (4). This frontpage is illustrated in Fig. 3(a). A click on the logo, present at the top of the screen on most pages, takes the user back to the frontpage.

The interaction design also includes a page with search functions that provide direct access to specific information. It is possible to make direct free text search or to search in lists of symptoms, diagnostics, treatments, and monitoring, see Fig. 3(b).

The main information in the system is structured after the archetypes. For each archetype, a number of headlines was defined. They gave the overall structure on the information about the archetype. This rather long text (up to 25 standard Word pages) would be extremely long when transformed to the small screen. The structure and the headlines were defined in co-operation with the archetype-writers/chief physicians. The text under each headline can then be unfolded by clicking a drop-down icon, see Fig. 3(c). The headlines also give ‘at a glance’ information on whether there are any

notes to the text by using a transparent icon of a document when no notes are available and a clear icon when notes has been inserted. The same icon with the '+' is the icon used when inserting notes to the text, see Fig. 3(c).

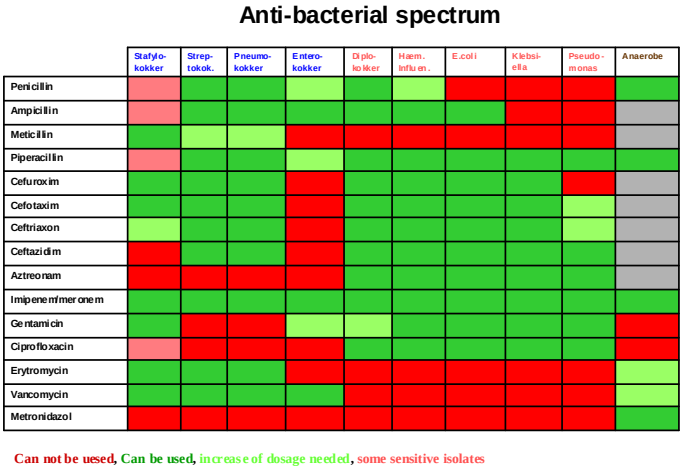

Fig. 4. A table from the ward instruction in full size.

The paper instructions included a set of tables with structured information. The transformation of these tables to the PDA was a particular challenge, because they were quite large. There is an example of one of the tables in Fig. 4. If this table was transformed to be fully visible on the PDA screen, it would be impossible to read. Thus only part of it could be visible on the screen. Yet the problem with that is that the contents of a cell in the table only make sense if it is related to other cells or at least to the column and row headers.

Fig. 5. Screen-dump of the table as shown on the small screen of the PDA.

The solution we implemented was a table with fixed column and row headers, where the user could scroll in both directions to get to a certain cell, see Fig. 5. The design of the digitized clinical ward instruction was implemented on a PDA. The implementation did not require changes to the design.

5 Evaluation

The prototype was distributed to the junior registrars at the ward and to the chief physician who had the educational responsibility for the registrars. They were not trained in the system, but they received a two-page laminated sheet that provided some information about getting started with the system and fitted in their pocket. They were instructed to work with the PDAs and explore their potentials. This exploration lasted for over one month and was followed by two evaluations.

17 physicians (16 registrars and one chief physician) participated in the evaluation of the digital ward instruction on the PDA. Eight registrars participated in the usability evaluation of the prototype. Seven registrars participated in the evaluation of the utility of the prototype. Both evaluations are described below.

5.1 Usability Evaluation

The first evaluation focused on usability. The digital ward instruction was evaluated in a classical usability evaluation [14]. This was conducted when the system had been used for 6 weeks.

The evaluation was conducted on site at the hospital, in the administrative section of the emergency ward in order to avoid disturbances. We were required to conduct the evaluation in this setting because we did not have the resources for taking the users to our usability lab. Given the exploratory nature of the study, we did not consider this as a major problem.

The users were seven junior registrars all on duty on the day of the evaluation. The evaluators were two usability experts who had a master thesis in HCI and significant experience with the classical approach. The two evaluators conducted a series of usability tests where each physician was sitting in a locker-room, solving a series of pre-defined tasks while thinking aloud. All tests were video recorded. The evaluators analyzed the video recordings separately. They also rated the severity on the scale: critical-serious-cosmetic [30]. Finally, they negotiated a joint list of usability problems with agreed severity ratings, see Table 1.

The evaluators identified 20 usability problems. This included 9 critical, 4 serious and 7 cosmetic problems, all related to the operability of the PDA interface. The list of usability problems emphasizes three main problems in the system:

- Navigation is not intuitive to the users
- The note function is poorly understood
- The table does not work satisfactorily, neither in terms of navigation nor in terms of content

In addition, post-test interviews uncovered a fundamental problem. The idea of the system is to “transfer” the paper instructions onto the PDA. However, several users expressed that this did not work because they could not gain enough overview from the small screen and read the instructions from it. Therefore, they did not use that part of the system.

Table 1. The problem list from the usability evaluation.

#	Description	Severity
1	Navigation: does not know that “medicin.dk” is an item in the main menu	Cosmetic
2	Instructions: does not know the function of ”quick checklist” in the instruction item on “acute serious asthma”	Critical
3	Navigation: is missing a “forward button” like the ”back button”	Critical
4	Instructions: believes erroneously that a click on the name of an instruction will activate it	Cosmetic
5	Instructions: believes erroneously that the “+” sign by an instruction will activate it	Serious
6	Navigation: does not know that the logo activates the main menu	Cosmetic
7	Navigation: is unable to find the link to the table (bacteria and penicillin)	Critical
8	Physical: the physical start button does not activate the main menu	Serious
9	Notes: does not know that the PDA has Dictaphone, camera and video	Cosmetic
10	Notes: does not know that there is a note function	Cosmetic
11	Notes: does not know how a note is created	Cosmetic
12	Search: cannot get back from the search page as there is no logo	Critical
13	Search: cannot find an instruction as search only works with the correct combination and order of words	Critical
14	Table: cannot get to the relevant cell as there is no horizontal scroll-bar	Critical
15	Table: cannot control the pointer pen to get to the relevant cell	Critical
16	Table: cannot find the relevant cell as the leftmost column has partly disappeared	Critical
17	Table: cannot read the relevant cell as there is an automatic home function when the pen is lifted from the screen	Serious
18	Table: misses a legend for the colour codes in table cells	Critical
19	Table: misses information about dosage of medicaments	Serious
20	Table: misses information about package size for medicaments	Cosmetic

An important feature is that the system provides access to an on-line medicine catalogue. This catalogue provides detailed information about each medicament that is available. All users emphasized the importance of this feature and the high quality of the information provided.

5.2 Utility Evaluation

The second evaluation focused on utility. The purpose was to identify how useful he digital ward instruction on the PDA was for the junior registrars in their work. It was conducted when the system had been used for six weeks.

This evaluation was based on a semi-structured qualitative interview. Two evaluators were present during an interview with one registrar at a time. It focused on the digital ward instruction, but there was a paper-made PDA artifact with a ‘blank screen’/white paper for writing, and the registrars were encouraged to use it to illustrate their points and as a trigger for reflection and new ideas for alternative designs. Seven junior registrars and one chief physician who was responsible for the

junior registrars' education participated. The two evaluators were HCI researchers with significant experience with the interpretive approach.

Fig. 6. A junior registrar writing and drawing design ideas on a paper-PDA.

In the interview, each physician was asked to solve pre-defined tasks. The dialogue about user experiences during the 6 weeks of using the prototype was considered the target information, capturing everyday obstacles and ideas. All interviews were video recorded. Based on notes and the video recordings, the evaluators produced a list of utility problems covering the following themes:

- Wireless network and IT-support
- Information access
- Mobile workers and technological islands
- High learning curve for beginners
- Conventional problems for mobile technologies

Wireless network and IT-support: Since one of the primary gains of the mobile technology was the access to on-line resources on the www, network problems were experienced as a serious obstacle. Only 3 of the junior registrars succeeded in getting online and only for a period, the longest being 3 weeks. The evaluation revealed a serious lack of infrastructure in the (rather old) hospital buildings. Only some parts of the buildings had wifi; the two medical wards had wifi while the casualty and the administrative building did not. Additionally, only 4 users were allowed on the network at a time, and 2-3 laptops on the wards were permanently used for accessing electronic health records, which left room for only 1-2 PDA users. The support of the PDA-users was also a serious problem. As explained by one of the junior registrars when asked why she did not ask the IT-department for support when she had network problems: "because then I was on night duty for a week and then I had 2 weeks on vacation and then we were so busy when I started up again so I just stopped using it".

Information access: A recurring reason for not using the PDA as the primary tool for information access was the lack of connection to on-line resources and the incomplete digitized ward instruction: only the 9 (out of 15) major and most used archetypes were transformed to the PDA due to time pressure on the side of both the interaction designers and the chief physicians at the ward. "I cannot use it when they are not all there" one of the junior registrars explained. "You like to think of a place where you have all your information" another registrar noticed.

Mobile workers and technological islands: The mobile doctors needed an application that was fully mobile in the sense of being used at whatever hospital or ward you are in contrast to the implemented ward specific 'island'. An IT strategy for introducing this type of technology must take the mobility of (junior) physicians into account. As explained by one of the junior registrars: "in two months I am leaving for general practice so I did not want to use energy on learning this technology and applications". During the first 18 month the registrars work at two different wards and in a general practice with different technologies, applications, policies etc. Thus supporting the mobility of junior registrars is not only about supporting the work within wards, but also about supporting mobility between wards.

High learning curve for beginners: "You really have to invest some time in it before it will pay off" one of the few experienced PDA-users explained. They did not experience a PDA as a 'walk-up-and-use' technology, but a demanding technology which users have to become familiar with, personalize or "tame" [6].

Conventional problems for mobile technologies: The evaluation also revealed a list of interaction problems: (a) too many clicks: "you have to start it up, open the program, log-on and make your search, while you would have been able to look it up in your book four times" as explained by one of the junior registrars; (b) too little screen space for reading long text; c) too difficult to find information with direct text search "we are used to looking at lists" one of the junior registrars explained referring to the contents in text books, reference books, indexes on the www, guidelines etc.; and (d) errors in two hyperlinks and one spelling mistake which reduced the value of the system.

6 Discussion

The results of the two evaluations came as a surprise. The usability problems uncovered a range of difficulties, although the transformation from paper to PDA and the design of the interaction was developed in close collaboration with the users.

The information implemented on the PDA is very complex. There is both a large amount of information, and the nature of the information very intricate and dense. This makes the transformation process interesting. The key decision was that the design was centered on archetypes. This provided a clear structuring mechanism when the paper instructions were cut into fragments that could be displayed on the mobile device. This worked well. The implementation of tables was less successful as the users experienced several usability problems when interacting with them.

The most striking result of the evaluation was the limited utility that the users had experienced. They had definitely not found the system particularly useful, and only a few of them had practiced use at a serious level. The study also confirmed the common experience that exploratory use of a prototype in the real context of use requires full access to information. In our case, this applies both to the information in the system and the access to the network.

In our prototype, neither the information in the system nor the network access were fully implemented. It has been emphasized that case studies are important for developing a better practice in usability evaluation [36], yet the argument also holds

for design activities. In the case study, we have reported from, the most interesting aspect is the transformation of complex information on paper onto a PDA. It turned out to be virtually impossible to evaluate the usability and utility of the PDAs, because the users could not abstract from the limitation. This can be seen as a specific occurrence of the general design tension between attention to specific content versus attention to general content [32].

It could be discussed whether we should have conducted and discussed the utility evaluation before the usability evaluation. If the system does not offer the required functionality, the users might not want to use it. Yet if the system is not usable, the utility will be hard to discover. This reflects the more general challenge of founding design on organizational fervour for quality in use, fit to context and value in the world [713].

The main impact of this case study is a better understanding of interaction design for PDA-based system combined with experience about key obstacles for evaluating the utility and usability of such a system. Moreover, the case illustrates the difficulties faced in the actual evaluation, e.g. the range of problems with the hospital's infrastructure that lead to a high rate of abandonment.

7 Conclusion

We have presented experiences from a case study of the design and evaluation of a prototype on a PDA that implements a complex textual paper instruction. The instruction is a training document for junior registrars in an emergency medical ward. The interaction design has been described in detail.

The PDA was evaluated both in terms of usability and utility. The usability evaluation revealed a variety of basic problems with the transformation from paper to the PDA prototype, including problems with navigation, activating functions and interacting with information in tables. The utility evaluation uncovered fundamental problems in the application domain, including practical problems with the PDA technology as well as organizational problems that limited the usefulness of the prototype. The evaluations uncovered a more fundamental lesson full benefit from an evaluation in a context like ours, requires a complete computerized solution and not just a prototype that provides a good implementation of the novel aspects of the design.

The design and evaluation of the prototype has emphasized new areas for future research. There is clearly a need for more cases of designing systems for accessing complex information on a PDA in an application domain like the one we have worked with. It would also be interesting to develop more general and firm guidelines for transforming complex information into an interaction design for a PDA. This will facilitate development and deployment of mobile devices in new application domains. We have not dealt with the ethical aspects [13], but they need to be considered prior to full deployment of systems that support decision making and capturing of information about patients.

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