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ABSTRACT

Mobile devices are becoming pervasive in medical informatics. A common practice among physicians is to take notes during ward rounds, which helps them write the formal medical note. MedNote is a mobile application designed to support this practice. We conducted an experimental evaluation, where seven medical interns watched a video projection of three clinical cases, using different devices (PDA, Tablet PC, Paper) to take notes. Participants were required to elaborate a formal medical note with the help of these personal notes. We measured the time required to complete the tasks as well as their perception of comfort with each device. Using the application proved to be faster in elaborating the formal note when compared to paper, and all users agreed that the structure of fields in MedNote was very useful as a guideline. In contrast, we found that entering data in MedNote was somewhat difficult and slow compared to using paper.

Keywords

Handheld computing, empirical evaluation, medical note application, TAM

INTRODUCTION

Healthcare professionals are increasingly adopting mobile computing devices (Stolworthy and Suszka, 2000). It has been estimated that approximately 40% of practicing physicians in the U.S. used Personal Digital Assistants (PDAs) in 2004, up from 19% in 2001, more than four times the overall percentage rate of adoption in the general population (Chin, 2005).

The most popular handheld medical applications today are ones which provide access to reference material, such as pharmacological databases (Lapinsky, 2004; Groote and Doranski, 2004). Increasingly, however, PDAs with wireless connectivity to a hospital information system provide physicians access to patient medical records from anywhere within the hospital. Even with their limited screen size, PDA's offer clear advantages from having this increased availability of information.

More recently, the introduction of Tablet PCs into the marketplace has provided hospital workers with additional alternatives to support their work through mobile computer technology (Spyglass 2004).

Although studies have been conducted which address the difficulties and challenges a user may have while capturing information on PDAs (Garvin, Otto, and McRae 2000; Wright et al. 2000), to our knowledge there are no previous empirical

evaluations reported in circumstances that emulate the working environment faced by these professionals. This has motivated the work presented in this paper.

Medical notes are an important component of a patient's medical record. During ward rounds, physicians frequently take notes on a piece of paper or a notepad. These notes usually reflect the doctor's perspective of the patient's medical condition and have a personal character. Eventually, physicians need to make an official medical note to file with the patient's medical records, and usually this is done based on personal annotations. Consequently, when elaborating this official note, it is common for practitioners to experience some difficulty and delay when transcribing information from notepads. This also represents a source of errors.

To assist physicians in creating and organizing the medical notes of their patients, we have developed and tested a handheld application called MedNote. The application offers predefined fields that follow the SOAP (Subjective, Objective, Analysis, and Plan) format, used by doctors to systematically present information about a patient. The structure of these fields provides physicians with a framework to be used as a guide during patient examination, facilitating the recall of important aspects of the patient's condition which should be taken into account. Notes are kept in the mobile device from which they may be transferred to a desktop computer for completion, then subsequently filed in the patient's medical record. The application has been designed to provide physicians quick and easy access to their annotations and reduce the time and effort involved in generating the official medical note.

In this paper we present an empirical evaluation of the potential of mobile devices such as PDAs and Tablet PCs in supporting the creation of medical notes through the use of MedNote. In the next section we describe the MedNote application. Following that, we describe the design of the experiment and the methodology applied in the study. The next section presents the results of the experiment, followed by a discussion. We then conclude by emphasizing our main findings and proposing directions for future work.

THE MEDNOTE MOBILE APPLICATION

MedNote is a mobile application designed to provide physicians quick and easy access to their annotations about a patient's condition, reducing the time and effort involved in generating the official medical note to be integrated within the patient's medical records. As the application may be run on either a PDA or Tablet PC, the two most popular mobile computing devices utilized by physicians, it is suitable to be used during ward rounds or at any other time when the physician is away from a desktop computer.

MedNote keeps annotations in a database on the mobile device from which the user may access them for review or modification. These notes are associated with patients in such a way that a physician may select a specific patient from a list and then be able to retrieve all notes related to that patient from the database displayed in chronological order (Figure 1). This enables the physician to monitor the patient's evolution according to his notes.

Figure 1. Screenshots of the MedNote application

The information captured in MedNote is classified in seven categories, each organized in a different field tab on the screen. The first and second tabs contain information that identifies the patient and his vital signs. The rest of the tabs correspond to information related to predefined fields that follow the SOAP format (*Subjective, Objective, Analysis, Plan*), used by physicians to document pertinent and descriptive information about a patient. The structure of these fields provides physicians with guidelines to proceed during the patient examination and helps them recall important details of the patient's condition that may be integrated into their notes.

The application's interface aims at helping the user enter data easily. In some fields the user gets a dropdown list menu so he may quickly select an option. On fields where a menu is not available, the user enters text directly on a textbox, in which case the user may use a predictive option where the application suggests words that match what he has entered so far. For this predictive option, three glossaries where used: common medical terms, drug names, and a general language dictionary.

Notes are kept in the mobile device from where they can be transferred to a desktop computer to be completed and filed in the patient's medical record. The exported file is in plain text format and may be opened with any text editor (Figure 2). These files also retain the same field structure as the database, separating the different categories related to the patient's condition, enabling easier elaboration into a more detailed medical note.

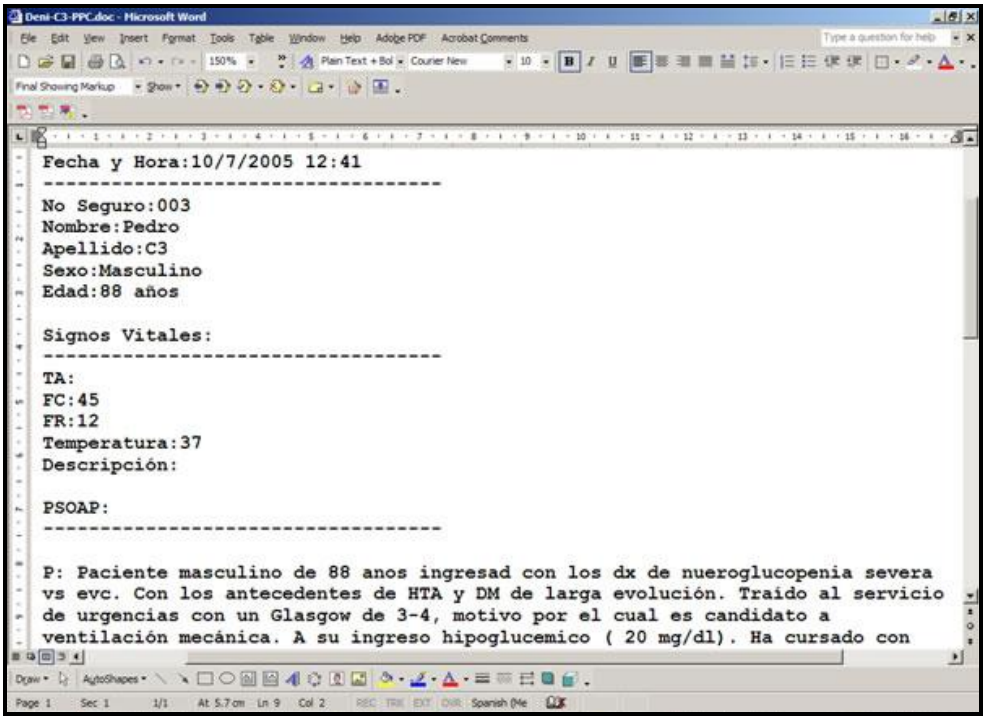

Figure 2 . Screenshot of the text file format

EXPERIMENTAL DESIGN

An experiment was designed to assess the degree to which MedNote helps medical interns in creating medical notes when compared with the use of paper. A group of seven interns from a local hospital were selected to participate given their familiarity with the use of PDAs. We assembled an experimental setting where work conditions were emulated by using a video projection of three clinical cases. This way, the interns could take notes as if they were following an attending physician on a typical ward round in the hospital. After viewing all three cases, participants were required to elaborate an official medical note with the help of their personal notes as they normally do in their everyday practice, using a desktop computer. All subjects watched the three videos describing the clinical cases and for each one, a different device (PDA, Tablet PC or Paper) was used to take notes, Table 1 shows the order in which cases and devices where used. We then measured the following variables: time to complete the tasks, number of tasks completed, and perception of difficulty and comfort when using each device. At the end of the experiment a questionnaire was applied and brief group interviews were conducted.

	Group 1			Group 2			
	TW	RZ	DA	DR	MG	ID	MB
PDA	Case 2	Case 1	Case 3	Case 2	Case 3	Case 3	Case 1
TabletPC	Case 1	Case 3	Case 2	Case 3	Case 2	Case 1	Case 2
Pen&Paper	Case 3	Case 2	Case 1	Case 1	Case 1	Case 2	Case 3

Table 1. Order of treatments across users

To guide our research we established three hypotheses:

- H1: The elaboration of a formal medical note is faster when using the application than when working with paper.

This hypothesis establishes that it is faster to elaborate a formal, or final medical note, by using MedNote than pen and paper. MedNote indeed was designed precisely to address this issue. Several design decisions were made with this in mind, including the use of the SOAP format to serve as a guideline for information capture, the use of a medical vocabulary to ease data entry, and the synchronization of the medical note with the PC. In this regard, proving this hypothesis will validate the design of MedNote itself and might predict its adoption.

- H2: Information capture is slower on the PDA than with paper

The informal notes that interns write during ward rounds are only used by them to produce the final version of the medical note. In this regards, interns do not need to pay attention to their calligraphy, thus they can write relatively fast. In contrast the subjects are not used to writing long texts on a PDA. This is one of the reasons why portable keyboards for PDAs have become popular among users with these needs. Familiarity and experience might play an important role in writing speed, as we can see nowadays teenage users of cell phones typing faster than they write in paper.

- H3: Users find it more comfortable to use a PDA than a Tablet PC.

The third and last hypothesis establishes that users will perceive notable differences in comfort when using a PDA than a Tablet PC for reasons such as size, weight, heat, etc.

The subjects for this study were selected from a sample of 20 medical interns from a mid-size public hospital who were queried in a questionnaire regarding their familiarity with the use of PDAs and computer technology to elaborate medical notes in the hospital. Among these interns we invited those who filled our criteria to participate in the study (at least six months experience as medical interns, significant knowledge of PDA's and time availability to participate) and seven responded to our invitation, six of them owned a PDA and had been using it for more than three months. All of these subjects reported that they routinely use paper and pen to write their notes during rounds, with four reporting that they occasionally use a PDA to write notes.

All seven subjects agreed that it is important to take notes during ward rounds; however two of them recognized that they do not do it as often as they should. Six interns declared using a specific sequence (the SOAP format) and they all used abbreviations while taking notes. Four out of seven said they have to re-write notes at least once a week because of errors committed during note taking.

EXPERIMENTAL SETUP

Prior to the experiment, our research team consulted an attending physician in a local hospital. The physician helped us to select three real clinical cases which were suitable in clinical content for the medical interns to take notes. The same

physician portrayed in the videotape as the attending physician, whose examination and clinical summary of the simulated patients was conducted audibly within the video recording of all three cases (Figure 3). The video was recorded within hospital facilities to include all the routine artifacts of a typical hospital round environment; we had a member of our team portray as each bedridden patient, while the physician reviewed the case using artifacts such as stethoscope, x-rays, ECG's, and medical records. While the clinical cases where based upon actual admitted patients to the hospital, all identifiers such as names and other personal information was omitted to preserve the patients' privacy.

Figure 3. Snapshot of the projected video

Three PDAs and two Tablet PCs were prepared for the experiment. The application was identically installed on all PDAs and Tablet PCs. We next captured the identifying information (name, age, gender) of each patient, leaving blank all other fields for the elaboration of the medical note.

We conditioned two rooms for the experiment. The first room (Projection Room) was used to explain the logistics of the experiment, give the subjects a hands-on tutorial and ran the projection of cases using a large screen and loudspeakers, (Figure 4). While medical interns were taking notes, we took still pictures and recorded video. We also recorded all keystrokes and annotation gestures of subjects using the PDA or Tablet PC as they elaborated their notes in real time.

Figure 4 . Projection Room

In the second room (Computer Lab), subjects where required to elaborate the final official note using a desktop computer. In this situation, for each patient case to be documented, subjects had available to them either a paper note or the corresponding text files from the assigned mobile device displayed on the desktop (Figure 5). Finally, all subjects were asked to complete a questionnaire that was followed by a brief group interview .

Figure 5. Computer Lab

EXPERIMENTAL PROCEDURE

The experiment was conducted in the following phases, as described below:

Phase 0. First, a preliminary presentation was given to the subjects in which the mechanics and chronology of the experiment were clearly described. A demonstration followed, in which the input functionality of the application MedNote was described. Finally, subjects were assigned alternatively, the PDA or Tablet PC devices within which the MedNote application was installed, in order to gain a hands-on familiarity with the features through direct interaction, as well as to provide an opportunity to ask questions or clarify any aspects of their operation.

Phase 1. Having been properly oriented to the experiment and the corresponding devices, the subjects were then directed to consider the scenario of a typical rounding patient consultation, in which they were required to carefully observe and listen to the presentation of a number of cases, while attempting to personally document any pertinent details of the patient into their mobile device or paper for later recall. The subjects were then shown the video projection of one of three cases. Each case was shown without interruption. The subjects were situated in a semi-circle at the foot of the bed of the simulated patient, allowing them the opportunity to interact with one another as they often do in an actual patient encounter. The participants concurrently wrote their preliminary medical notes for each of the three assigned experimental conditions. The assignment of each device was provided using a within subjects arrangement as detailed in Table I.

As subjects viewed the video and wrote their medical notes, those using a mobile device had their keystroke annotations monitored with the MORAE usability metric software. In the case of the Tablet PC, the application was installed directly on the device, whereas in the case of the PDA, the device was coupled by cable to a laptop computer in which the monitoring software was installed.

At the conclusion of each case, those using the application MedNote had their notes archived in a text file having an identifier of the user and corresponding case.

Phase 2. To initiate this phase, all notes generated with MedNote had their text files automatically transferred to a desktop computer. Alternatively, those notes originally generated on paper required the manual keyboard entry of the information to the desktop PC. The task to be performed in this phase of the experiment, was then to elaborate a final medical note for each of the three medical cases presented based upon the data generated by each of the three different operational modalities.

During this phase all working sessions were monitored and recorded.

Phase 3. A questionnaire was then distributed among the subjects containing inquiries related to their impressions of the MedNote application as well as of the two mobile devices used during the experiment.

Phase 4. To complete the experiment, a final interview was conducted, inquiring subjects about their distinct opinions, questions and suggestions for improving the application, as well as their impressions of the utility of such mobile devices for the elaboration of medical notes.

RESULTS

Using the monitoring software we were able to measure the time it took users to complete the formal notes using the desktop computer, and the personal notes they took on different devices. Table 2 presents the average times for each device.

	Mean	Standard Deviation
PDA	13:40	01:26
Tablet PC	14:17	01:55
Paper	17:40	04:02

Table 2. Average times in minutes using PDA, Tablet PC, and Paper to elaborate the formal medical note.

We also measured the extension of notes taken using each device. Generally speaking, notes taken using the application tended to be shorter, had more abbreviations, and were less descriptive than the ones taken using paper and pen (Table 3).

	TW	RZ	DA	DR	MG	ID	MB	Average	Standard Deviation
PDA	25	43	81	61	65	105	41	60.14	26.97
Tablet PC	19	97	48	85	57	25	57	55.43	28.62
Paper	122	134	59	80	84	127	153	108.43	34.19

Table 3. Average word count found on the notes produced with each device.

The data collected from the questionnaire applied at the end of the study was classified according to three factors of the TAM methodology (Davis, F. and Venkatesh, V. 1996): Usefulness of the application, perception of ease of use, and intention of use. In the questionnaire, we asked 14 questions using a seven-point Likert scale with anchors ranging from strongly disagree(1) to strongly agree(7), to measure the subjects perception of usefulness (6 questions), perceived ease of use (6 questions), and intention of use (2 questions). All questions referred to the MedNote applications and not to a specific device (TabletPC or PDA).

Table 4 summarizes these results, showing the number of question on each category along with the mean and mode values.

	Number of Questions	Mean	Mode
Usefulness	6	5.1	6.0
Ease of Use	6	5.3	6.0
Intention of use	2	6.0	6.0

Table 4. Summary of results obtained on the questionnaire applied at the end of experiment.

DISCUSSION

The results of the experiment provide evidence supporting our hypothesis as discussed next.

H1: The elaboration of a formal medical note is faster when using the application than when working with paper.

As shown in Table 2, using the application proved to be faster in elaborating the official note when compared against the use of paper: PDA users were 22.65% faster and Tablet PC users 19.15% faster. An analysis of the session shows that the improved performance was due to the fact that when using paper, the interns had to type the whole medical note, while PDA and Tablet PC users began with the digital version of the notes they took while watching the videos.

This conclusion is supported by comments from the users in the final interview. They expressed that it helped them having a structured startup sheet, and then just expand the description of each section.

H2: Information capture is slower on the PDA than with paper.

When comparing the notes that users wrote using the PDA and Tablet PC against the ones using Paper and Pen, we observed that the latter are more extensive and more descriptive; on average users wrote 60.14 words using the PDA and 55.43 words using the Tablet PC for each note (See Table 3). On the other hand, when using paper, they wrote 108.43 words on average per note. This evidence supports that users could write more words using paper than using the application given the same amount of time, hence we may conclude that capturing information in the PDA or Tablet PC was considerably slower.

This conclusion was reinforced by our finding in the final interview, where they expressly told us that it was somewhat difficult using the virtual keyboard available for data entry in the application, which slowed them down. They suggested using letter recognition or graffiti instead.

Based on this information we may conclude that given the actual state of the application it is slower to capture information than using paper and pen, however we believe that with some modifications, the application could be more competitive in this issue.

H3: Users find it more comfortable to use a PDA than a Tablet PC.

According to the questionnaire applied at the end of the experiment, using a seven-point Likert scale with anchors ranging from strongly disagree(1) to strongly agree(7), we observe a wide difference between users' perception of comfort between these two devices. For the PDA the average of users' opinions was 5.0, showing that they slightly agree with the idea of the PDA being comfortable for taking notes during ward rounds. On the other hand, the average user opinion about the Tablet PC being comfortable was 2.6 (between disagree and slightly disagree). We also should notice that paper got a rating of 6.4 which means they think that using paper is the most comfortable way for taking notes.

In addition, during the final interview users told us that the Tablet PC was too heavy to be carried around during ward rounds, specially if we take into account the fact that medical interns already have to carry several artifacts during rounds, which makes the PDA a better option for this purpose. This was confirmed by our own observations during the sessions, where we noticed that Tablet PC users felt uncomfortable carrying the Tablet PC after several minutes of use. For instance, they would often move the device to find a more suitable position to write.

These results provide important evidence in support of this hypothesis.

OTHER FINDINGS

An important feature of the application is its ability to provide a guideline for elaborating the medical note. This was validated when we found through the monitoring software (Morae) that one of the users reused (copy and paste) the format provided by the application to create a formal note that was based on information he had on paper. This feature was expressly commented during the interview as one of the most interesting features of MedNote.

Users where very motivated during the experiment, they felt that it would not be difficult to learn to use the application, they think that it would help them improve their general performance at work and that they showed disposition to adopt the technology in their workplace.

From the final interview we obtained several suggestions for improving the application, such as adding more medical vocabulary to the word prediction functionality, allow for the use of letter recognition data entry, reduce the number of open fields replacing them with option menus, and even incorporating voice notes and digital pictures of the patients' cases.

CONCLUSIONS

As mobile devices are becoming commonplace in medical environments, we require mobile medical application design to be more conscious of the actual needs of medical professionals. It is through the evaluation in close contact with physicians and nurses that we may develop such applications.

While an application of this nature may improve the time that medical interns take to create the official note to be filed in the patient's record, still some improvements need to be made in order to facilitate data entry while the user is in the actual process of taking notes at bedside. On the other hand, when comparing the PDA with the Tablet PC, we believe that there is a tradeoff that must be considered when designing an application, since gaining screen real state with a Tablet PC may decrease ease of use and portability when compared to using a PDA.

There is an increasing interest in incorporating mobile information technology to the medical ambience; medical interns feel that applications like the one presented here could help them to improve their performance at work.

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